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12 Aug 2005

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Dear Ms. Constantinescu and Ms. Tan:

The August 12, 2005, *Draft Site 22 Post-Construction Operations, Maintenance, and Monitoring Plan Addendum* is enclosed for your review. The final version of this document will be an addendum to the September 16, 2003, *Post-Construction Operations, Maintenance, and Monitoring Plan* for Site 22.

This document has been prepared for the Navy's environmental restoration at Moffett Field. Please contact me, at 619-532-0952, if you have any questions or need clarification.

Sincerely,

Signature on File

RICHARD C. WEISSENBORN
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By direction of the Director

Enclosure: 1. *Draft Site 22 Post-Construction Operations, Maintenance, and Monitoring Plan Addendum*

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**DRAFT
SITE 22
POST-CONSTRUCTION
OPERATIONS, MAINTENANCE,
AND MONITORING PLAN ADDENDUM
Revision 0
August 12, 2005**

**FORMER NAVAL AIR STATION MOFFETT FIELD
MOFFETT FIELD, CALIFORNIA**

**Base Realignment and Closure
Program Management Office West
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**CONTRACT NO. N68711-98-D-5713
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**DRAFT
SITE 22
POST-CONSTRUCTION
OPERATIONS, MAINTENANCE,
AND MONITORING PLAN ADDENDUM
Revision 0
August 12, 2005**

**FORMER NAVAL AIR STATION MOFFETT FIELD
MOFFETT FIELD, CALIFORNIA**

DCN: FWSD-RAC-05-1273



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ABBREVIATIONS AND ACRONYMS

µg/L	micrograms per liter
1,4-DCB	1,4-dichlorobenzene
ac	acute
AF	attenuation factor
ARAR	applicable or relevant and appropriate requirement
AT123D	Analytical Transient 1-, 2-, 3-Dimensional
AWQC	ambient water quality criteria
BeP	bis(2-ethylhexyl)phthalate
bgs	below ground surface
BHC	benzene hexachloride
CAS	chemical abstract system
CCL	calculated concentration limit
CCR	California Code of Regulations
ch	chronic
cis-1,2-DCE	cis-1,2-dichloroethene
CMC	criterion maximum concentration
cm/sec	centimeter per second
COC	constituent of concern
DCE	dichloroethene
EPA	U.S. Environmental Protection Agency
fw	freshwater
gpd	gallons per day
HLA	Harding Lawson Associates
IT	International Technology Corporation
J	estimated value
K _{oc}	soil-water partitioning coefficient
MDL	method detection limit
MEW	Middlefield-Ellis-Whisman
mg/L	milligrams per liter
mL/g	milliliters per gram

ABBREVIATIONS AND ACRONYMS

(Continued)

MP	monitoring parameter
MS	measurably significant
msl	mean sea level
NA	not available
NAS	Naval Air Station
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
OMMP	Operations, Maintenance, and Monitoring Plan
ORNL	Oak Ridge National Laboratory
POC	point of compliance
POE	point of exposure
ppt	parts per thousand
PRC	PRC Environmental Management
RL	reporting level
ROD	Record of Decision
RWQCB	Regional Water Quality Control Board
SF	safety factor
SQL	sample quantitation limit
SQuiRT™	Screening Quick Reference Tables
SVOC	semivolatile organic compound
sw	saltwater
SWRCB	State Water Resources Control Board
TCE	trichloroethene
TDS	total dissolved solids
TtEMI	Tetra Tech EM, Inc.
TtFW	Tetra Tech FW, Inc.
VOC	volatile organic compound

EXECUTIVE SUMMARY

The Department of the Navy (Navy) is conducting environmental restoration activities at former Naval Air Station Moffett Field (Moffett), located near Mountain View, California. This Post-Construction Operation, Maintenance, and Monitoring Plan Addendum describes the groundwater evaluation process and landfill gas (methane) monitoring program at the Site 22 Landfill, in accordance with the Record of Decision (ROD). The ROD for the Site 22 Landfill requires the Navy to comply with California Code of Regulations Title 27, Subchapter 3.

The Site 22 Landfill covers approximately 9.4 acres and contains an estimated total refuse (waste) volume of 92,000 cubic yards. The site was used as an active landfill from 1950 through 1967. The refuse is believed to consist primarily of domestic waste, as confirmed through exploratory trenching. The ROD specified that a biotic barrier, comprised of layers of soil, gravel, concrete slurry, and cobblestone be laid over the landfill to prevent animals from burrowing into the refuse. This was accomplished in the spring of 2003, including the installation of landfill gas monitoring wells and additional groundwater monitoring wells in October 2003. The Site 22 Landfill underlies holes 6 and 7 of a golf course, which is operated by the United States Air Force. The fairway and putting greens for these holes are located on top of the landfill.

The geology beneath the Site 22 Landfill consists of a complex interfingering of fine-grained units. As described in the ROD, groundwater beneath the site is neither considered a potable water source, nor is it used for agricultural purposes. Shallow groundwater beneath Site 22 is found in the upper portion of the A aquifer, flows toward the west, and appears to be influenced by pumping at Building 191, which discharges water into the Northern Channel. The primary potential receptors are ecological.

Groundwater beneath Site 22 flows predominantly toward the west. A north-south-oriented groundwater divide is interpreted to exist. The location of the hydraulic divide is to the east of the refuse.

Calculated groundwater concentration limits are proposed for Site 22 based on the site conceptual model. Appropriate screening criteria were selected for the constituents of concern (COCs). The physical and chemical changes that take place in the groundwater prior to discharging at the point of exposure (POE) were modeled using an U.S. Environmental Protection Agency (EPA)-approved analytical model (Analytical Transient 1-, 2-, 3-Dimensional [AT123D]) that considers advection-dispersion, sorption, and degradation as contaminants migrate through groundwater. The modeled results yielded a concentration ratio that was used to calculate compound-specific attenuation factors. The attenuation factor was multiplied by the

screening criteria for each COC to calculate a calculated concentration limit (CCL) that would be protective of ecological receptors at the POE.

Based on the groundwater flow direction determined during the baseline sampling activities conducted from November 2003 through October 2004, the monitoring points for Site 22 include downgradient wells WGC2-8 through WGC2-11, upgradient wells WGC2-4 and WGC2-13, and reference wells WGC2-6 and WGC2-12. The point of compliance for Site 22 is the downgradient vertical boundary along the west side of the landfill from monitoring well WGC2-8 through monitoring well WGC2-11.

The groundwater evaluation process at the Site 22 Landfill involves comparing the sampled groundwater analytical data to CCLs. If downgradient analytical data are lower than or equal to the respective CCLs, then no further action is necessary. If the downgradient analytical data are greater than the respective CCLs, then an evaluation is required. The downgradient analytical data are checked against the upgradient and reference analytical data to determine if the landfill is the potential cause. If the landfill is not the cause, detection monitoring will continue. If the landfill is suspected of being the cause, a statistical analysis will be made. If the analytical data are determined to be statistically significant, the data are considered potentially measurably significant. The EPA and Regional Water Quality Control Board, San Francisco Bay Region, will be notified, and the data will be verified by additional sampling. Verification samples will be collected within 30 days of receipt of the validated data from the previous sampling event. The verification samples will be analyzed for only those analytes that exceeded the CCL in the initial sampling event that indicated a potential release from the landfill. If the data are not verified in two out of three consecutive sampling events, then detection monitoring will continue. If the data are verified in two out of three consecutive sampling events, then the indication of being measurably significant is confirmed. If this occurs, the agencies will be notified, and an evaluation-monitoring program will be initiated.

Samples will be analyzed semiannually for monitoring parameters (MPs). MPs include physical and analytical parameters. The physical MPs are temperature, conductivity, dissolved oxygen, salinity, pH, and turbidity. The analytical MPs proposed for Site 22 are chloroform, 1,2-dichloroethene, trichloroethene, and xylene. Analytical MPs were selected based on the criteria in Title 27 California Code of Regulations, including frequency of detections, analyte mobility, analyte persistence, potential degradation products, chemical similarities, toxicity to aquatic receptors, and the reported operational history of the Site 22 Landfill. Groundwater samples will be collected and analyzed for the entire list of COCs every 5 years.

The Navy proposes semiannual water level measurements and sampling, once at low groundwater elevations and once at high groundwater elevations, based on the seasonal variations in water levels, a consistent groundwater flow direction and gradient, and minor

seasonality in the chemical data. Sampling is proposed to be conducted when the water level is the highest (February) and when the water levels are near their lowest (August).

The purpose of the methane detection monitoring program is to evaluate whether methane gas is migrating from the landfill. The evaluation is conducted through monitoring of methane at the site boundary to ensure that methane concentrations at the landfill boundary do not exceed 5 percent by volume in air. It is proposed that methane monitoring be conducted quarterly for the first 5 years following the completion of the cap construction, and re-evaluated for frequency at that time.

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1.0 INTRODUCTION

As part of the Installation Restoration Program, the Department of the Navy (Navy) is conducting environmental restoration activities at former Naval Air Station Moffett Field (Moffett), Moffett Field, California (Figure 1-1). The Installation Restoration Program was established by the Department of Defense to identify, evaluate, and control the spread of contaminants from historical hazardous waste sites. The work is coordinated through the U.S. Environmental Protection Agency (EPA), Region 9 and the Regional Water Quality Control Board (RWQCB), San Francisco Bay Region, through a Federal Facilities Agreement.

This document has been prepared on behalf of Navy's Base Realignment and Closure Program Management Office West, under Contract Task Order No. 0085, issued under Naval Facilities Engineering Command Southwest Remedial Action Contract N68711-98-D-5713.

1.1 OBJECTIVE AND DOCUMENT ORGANIZATION

This Operations, Maintenance, and Monitoring Plan (OMMP) Addendum is a supplement to the original OMMP (Tetra Tech FW, Inc. [TtFW], 2003), and presents the groundwater evaluation process (detection monitoring program), including the calculated concentration limits (CCLs) for each constituent of concern (COC), monitoring points, point of compliance (POC), data evaluation process, monitoring parameters (MPs), monitoring frequency, and the landfill gas (methane) monitoring program, including the monitoring locations and monitoring frequency for the Site 22 Landfill located at Moffett (Figure 1-2). The content of this report meets the requirements stated in the Record of Decision (ROD) (Navy, 2002) for Site 22, and the applicable sections of the California Code of Regulations (CCR), Title 27, Subchapter 3 and Subchapter 4. The purpose of the groundwater detection monitoring program is to evaluate whether there has been a release from the landfill. The purpose of the methane monitoring program is to determine whether methane gas is migrating from the landfill.

This OMMP Addendum is organized as follows:

- **Section 1.0** provides objective and document organization, regulatory framework, and an overview of the required elements for the Site 22 groundwater and methane detection monitoring programs.
- **Section 2.0** presents the site background, description and history of the Site 22 Landfill, geology/hydrogeology, and exposure pathway analysis and receptors.
- **Section 3.0** provides groundwater sampling results for groundwater monitoring activities conducted at the Site 22 Landfill from September 1994 through October 2004.
- **Section 4.0** provides the CCLs, defines the monitoring points, POC, describes the data evaluation process, MPs, and frequency and schedule for groundwater monitoring.

- **Section 5.0** provides the monitoring points and frequency for methane monitoring.
- **Section 6.0** provides a summary of the document.
- **Section 7.0** lists the references cited in the text.
- Tables and figures follow the text.
- **Appendix A** presents the potentiometric surface maps for the baseline monitoring period from November 2003 through October 2004.
- **Appendix B** presents the analytical results for COCs in groundwater collected at Site 22 from November 2003 through October 2004.
- **Appendix C** provides supporting information regarding the surrogate chemicals used to develop the screening level criteria for the CCLs.
- **Appendix D** describes the calculation of concentration ratios used to develop attenuation factors, including objectives, and results.
- **Appendix E** describes the groundwater data evaluation process and statistical analysis, including a discussion of the guidance documents, software, background concentrations, handling of non-detects and estimated values, analytical process, and methodology.

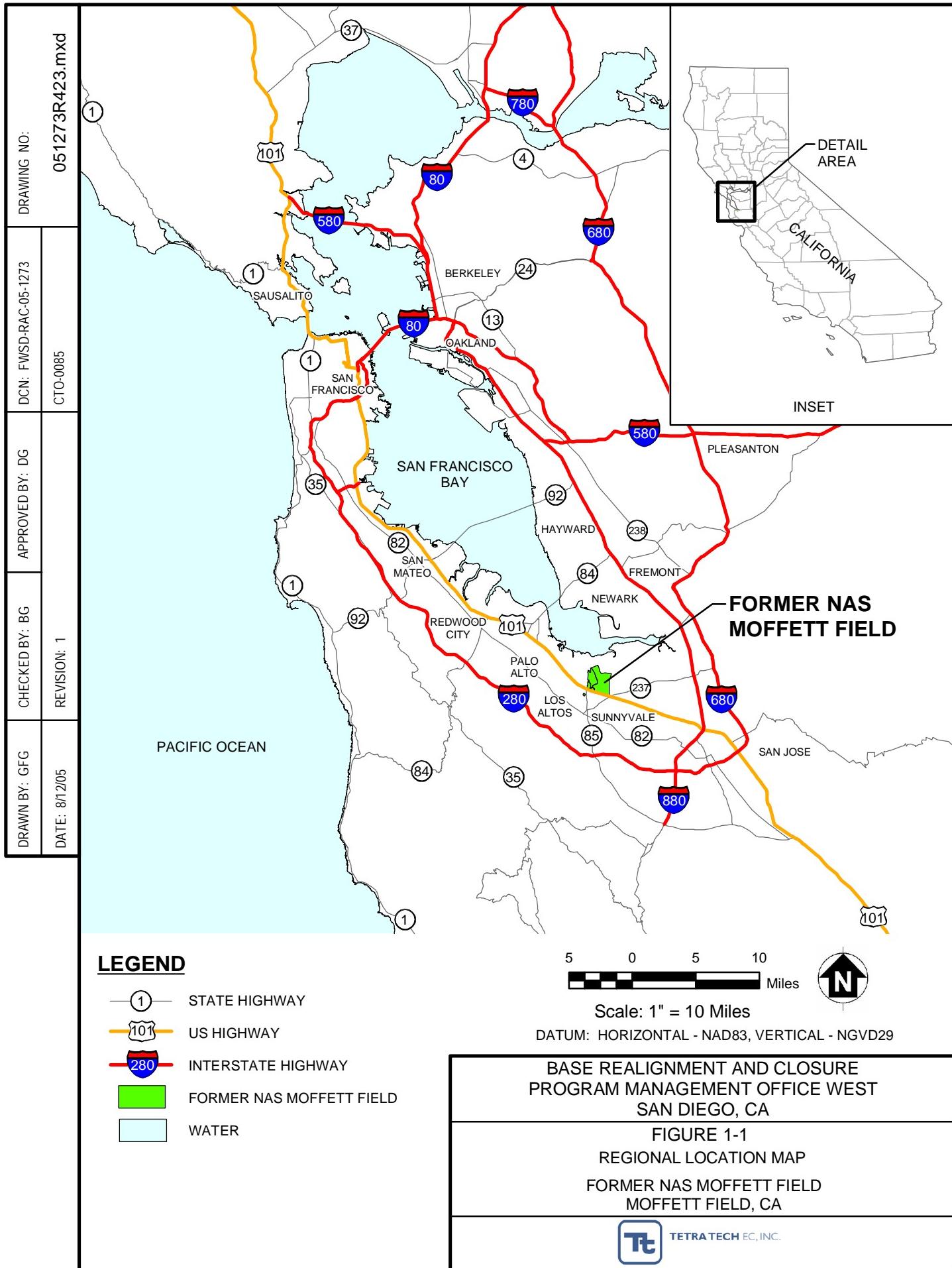
1.2 REGULATORY FRAMEWORK

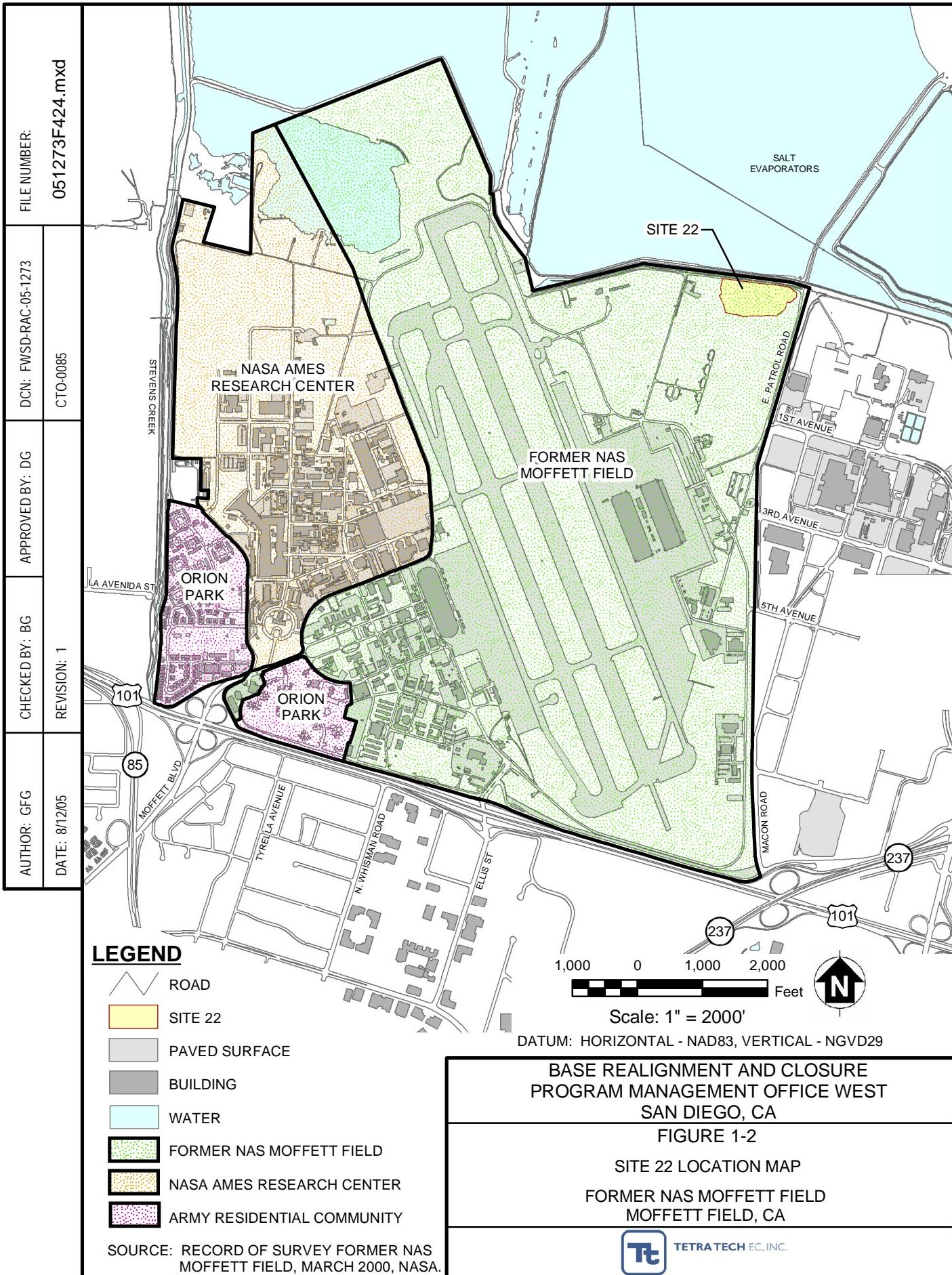
The regulatory framework for the selected response actions at the Site 22 Landfill involves numerous government agencies and their respective applicable or relevant and appropriate requirements (ARARs), as identified in the ROD (Navy, 2002). Regulatory agencies for Site 22 include EPA; the RWQCB, San Francisco Bay Region; the California Integrated Waste Management Board; and the Santa Clara County Department of Environmental Health, which conducts quarterly inspections.

EPA placed Moffett on the National Priorities List in July 1987. The Comprehensive Environmental Response, Compensation, and Liability Act prescribes a remedial investigation/feasibility study process. The Site 22 Landfill was characterized in the Station-wide Remedial Investigation (PRC Environmental Management, Inc. [PRC], 1996) and the Additional Sites Investigation Phase II Report (PRC, 1995). The Final ROD was signed in June 2002 (Navy, 2002).

1.2.1 Record of Decision

The ROD for Site 22 (Navy, 2002) summarizes Site 22 characteristics and risks, describes and evaluates the remedial alternatives, documents significant changes, identifies the selected remedy, identifies statutory determinations (including compliance with ARARs), presents a responsiveness summary, and provides references. The major elements of the selected remedy for Site 22 are:





- Installation of a barrier to prevent burrowing animals from disturbing the subsurface contamination
- Management of surface water flows across the site
- Enactment of institutional controls to prevent excavation of waste materials
- Monitoring of groundwater and gas (methane) in the vicinity of the site

The groundwater underlying Site 22, as described in the ROD, has a high total dissolved solids (TDS) concentration (greater than 3,000 milligrams per liter [mg/L]), which limits its use. According to the California State Water Resources Control Board's Resolution 88-63, water with a TDS level greater than 3,000 mg/L is not considered a potential source of drinking water. Therefore, the Site 22 detection monitoring program is designed to be protective of potential ecological receptors.

The landfill groundwater monitoring ARARs identified in the ROD include substantive portions of the groundwater monitoring requirements in Title 27 CCR and the 1995 San Francisco Bay Basin Plan. The ROD defines the regulatory approach to be used in groundwater monitoring and closely follows the requirements of Title 27 CCR.

The ROD directs the Navy to develop a groundwater monitoring program that will incorporate the substantive provisions of the following requirements:

- Required programs [27 CCR, §20385 (a)(1), (a)(2), (a)(3), (c)]
- Water quality protection standard [27 CCR, §20390 (a)]
- COCs [27 CCR, §20395 (a)]
- CCLs [27 CCR, §20400 (a), (d), (g)]
- Water quality monitoring and system requirements [27 CCR, §20415 (b)(1)(A-C), (e)]
- Detection monitoring program (27 CCR, §20420)
- Evaluation monitoring program [27 CCR, §20425 (b), (c), (d)(1), (d)(2), (e), (f), (g), (h), (i)]

The landfill methane monitoring ARARs identified in the ROD (Navy, 2002) are specified in Title 27 CCR, §20921 (a)(1)(2)(3). This regulation requires that methane be monitored to ensure that landfill gas (methane) is monitored and controlled, as required.

1.3 GROUNDWATER DETECTION MONITORING PROGRAM

The purpose of the groundwater detection monitoring program is to evaluate whether there has been a release from the landfill. The evaluation is conducted through monitoring of groundwater at the site, statistical evaluation, and comparison of the data to CCLs set pursuant to the ROD, the OMMP, and the applicable regulations. Each of the key elements of the groundwater

detection monitoring program is summarized below and described in greater detail in Section 4.0 of this document.

1.3.1 Water Quality Protection Standard

The Water Quality Protection Standard (Water Standard) is identified in Title 27 CCR, §20390, and consists of the following:

- List of COCs (Title 27 CCR, §20395)
- CCLs for COCs (Title 27 CCR, §20400)
- Monitoring points and POC (Title 27 CCR, §20405)

The Water Standard applies during the post-closure monitoring period and during any subsequent compliance period (Title 27 CCR, § 20410). If a detection monitoring program is conducted in conjunction with a corrective action program for a unit [Title 27 CCR, §20385(c)], separate Water Standards may be established for each program. The COCs were established in the ROD (Navy 2002), and the monitoring points and POC were established in the OMMP (TtFW, 2003). However, as a result of the installation of the biotic barrier at Site 22, a hydraulic divide exists to the east of the landfill impacting upgradient conditions, but not the overall groundwater flow direction. Therefore, this OMMP Addendum includes new proposed monitoring points and a new POC. The new monitoring points and POC have been discussed and agreed upon by the Navy, EPA, and the RWQCB.

1.3.1.1 Constituents of Concern

Title 27 CCR, §20395 states that the COC list “shall include waste constituents, reaction products, and hazardous constituents that are reasonably expected to be in or derived from waste contained in the Unit.” The COCs presented in the ROD (Navy, 2002) were developed in accordance with the applicable regulations and are based on the historical information concerning types of materials potentially placed in the Site 22 Landfill. The COCs, as specified in the ROD, are presented in Table 1-1.

1.3.1.2 Calculated Concentration Limits

CCLs for Site 22 are presented within this document and were developed in accordance with the ROD, the OMMP, and applicable regulations (Title 27 CCR, §20400) and the RWQCB Basin Plan objectives. The concentration limits presented in Section 4.1 are based on the appropriate surface water screening criteria for ecological receptors, as modified by an attenuation factor (AF). The AFs were necessary to account for natural groundwater processes of advection-dispersion, sorption, and degradation when comparing groundwater analytical samples to surface water criteria. The development of the CCLs is described in Section 4.1, with supporting

TABLE 1-1**CONSTITUENTS OF CONCERN, SITE 22, FORMER NAS MOFFETT FIELD**

CAS^(a) #	VOCs
71-43-2	Benzene
108-90-7	Chlorobenzene
67-66-3	Chloroform
156-59-2	cis-1,2-Dichloroethene
100-41-4	Ethylbenzene
108-88-3	Toluene
79-01-6	Trichloroethene
NA ^(a)	Xylene (Total)
75-01-4	Vinyl chloride
CAS #	Pesticides
309-00-2	Aldrin
58-89-9	gamma-BHC (Lindane)
CAS #	SVOCs
106-46-7	1,4-Dichlorobenzene
91-57-6	2-Methylnaphthalene
106-44-5	4-Methylphenol
117-81-7	bis(2-Ethylhexyl)phthalate
86-74-8	Carbazole
132-64-9	Dibenzofuran
84-66-2	Diethylphthalate
91-20-3	Naphthalene
86-73-7	Fluorene

Notes:

(a) CAS numbers exist for individual isomers.

Abbreviations and Acronyms:

BHC – benzene hexachloride

CAS – chemical abstract system

NA - not available

NAS – Naval Air Station

SVOC – semivolatile organic compound

VOC – volatile organic compound

information about the derivation of concentration ratios used to develop the AFs provided in Appendix D.

1.3.1.3 Monitoring Points and the Point of Compliance

Title 27 CCR, §20405 requires the identification of monitoring points and the POC. Monitoring points are defined in Title 27 as “a well, device, or location at which monitoring is conducted and at which the Water Standard applies.” The Site 22 monitoring points are described in Section 4.2. The POC is a vertical surface located at the hydraulically downgradient limit of the landfill that extends through the uppermost aquifer underlying the landfill. The Water Standard is applied at the POC. The POC is described in Section 4.3

1.3.2 Data Evaluation Process

Routine monitoring [Title 27 CCR, §20420(f)] is conducted during detection monitoring for physical and analytical parameters. To determine if there has been a release from the unit, the Navy will determine whether data are measurably significant¹ and verify the data. Background and reference values and CCLs will be used pursuant to the ROD, the OMMP, and this plan during data analyses. The data evaluation process is described in Section 4.4.

1.3.3 Monitoring Parameters

Title 27 CCR, §20164 defines MPs as a set of parameters that provides a reliable indication of a release from a unit. The MPs are a subset of the COCs and include physical parameters, waste constituents, and reaction products that may occur from the material within the landfill. The Site 22 MPs are presented in Section 4.5.

1.3.4 Monitoring Frequency

Title 27 CCR, §20415 requires regular sampling of monitoring points to assess the condition of groundwater at the site. Monitoring is required quarterly for the first year that a well is in place and can be modified subsequently, pending regulatory approval. The Site 22 monitoring wells (WGC2-1 through WGC2-6) were sampled intermittently from September 1994 though April 1998. Baseline sampling of monitoring wells at Site 22 Landfill (WGC2-1, WGC2-4, WGC2-5, WGC2-6, WGC2-8, WGC2-9, WGC2-10, WGC2-11, WGC2-12, and WGC2-13) occurred from November 2003 through October 2004. The MPs proposed in this document will be analyzed semiannually. The list of COCs will be monitored every 5 years, as specified by Title 27 CCR, §20420(g).

¹ Measurably significant is defined as a change in the monitoring point data that, relative to the reference background value (or other approved reference value or distribution), is sufficient to indicate that a release has occurred (Section 4.4).

1.4 METHANE DETECTION MONITORING PROGRAM

The purpose of the methane detection monitoring program is to evaluate whether methane gas is migrating from the landfill. The evaluation is conducted through monitoring of methane at the site boundary to ensure that methane concentrations at the landfill boundary do not exceed 5 percent by volume in air, pursuant to the ROD, the OMMP, and the applicable regulations. Each of the key elements of the detection monitoring program is summarized below and described in greater detail in Section 5.0 of this document.

1.4.1 Monitoring Newwork

Title 27 CCR §20415 (e) requires that the monitoring systems be designed by a registered geologist or a registered civil engineer. The Site 22 methane monitoring network is described in Section 5.1.

1.4.2 Data Evaluation Process

Title 27 CCR, §20921 (a)(1)(2)(3) specifies the methane concentration limits in air at the landfill boundary. Methane will be monitored with direct measurement instrumentation to confirm that concentrations remain below 5 percent by volume in air at the site boundary. The Site 22 methane evaluation process is described in Section 5.2

1.4.3 Monitoring Frequency

The ROD (Navy, 2002) specifies quarterly monitoring of methane gas. The ROD (Navy, 2002) further specifies that after a minimum of 5 years of monitoring, if results show no evidence of significant impacts, the monitoring interval may later be less frequent, or monitoring may be deemed unnecessary. The Site 22 methane monitoring frequency is described in Section 5.3.

2.0 SITE CHARACTERIZATION

2.1 BACKGROUND

Moffett is located near the southern end of San Francisco Bay (see Figure 1-1). Moffett is bounded by saltwater evaporation ponds to the north, Stevens Creek to the west, US Highway 101 to the south, and the Lockheed Martin complex to the east. Moffett has served various military functions during the past 60 years.

In 1991, Naval Air Station Moffett Field was designated for closure as an active military base under the Department of Defense Base Realignment and Closure program. The property was transferred to the National Aeronautics and Space Administration (NASA) on July 1, 1994, and it was renamed Moffett Federal Airfield. In 2002, NASA changed the name to NASA AMES Research Center.

Federal and state tenants located at Moffett include the U.S. Army, U.S. Air Force, and California Air National Guard. Current Moffett uses include airfield operations, military facilities, and NASA research activities. Moffett also has a fully functional federal airport managed by the Facilities and Logistics Management Division. Facilities for military personnel and their families include family housing, a commissary, a military clinic, a service station, a U.S. Post Office, tennis courts, and an 18-hole golf course.

2.2 DESCRIPTION AND HISTORY OF THE SITE 22 LANDFILL

The Site 22 Landfill is located in the northeastern corner of Moffett. The Site 22 Landfill covers approximately 9.4 acres and contains an estimated total refuse (waste) volume of 92,000 cubic yards. The site was used as an active landfill from 1950 through 1967. The refuse is believed to consist primarily of domestic waste, as confirmed through exploratory trenching (Department of the Navy [Navy], 2002). Results of environmental investigations indicate that in some places, the waste is located beneath the groundwater table, while in others, waste is located near the surface (above the groundwater table). The Site 22 Landfill now underlies holes 6 and 7 of a golf course, which is operated by the U.S. Air Force. The fairway and putting greens for these holes are located on top of the landfill.

The Record of Decision (Navy, 2002) specified that a biotic barrier, comprised of layers of soil, gravel, concrete slurry, and cobblestone be laid over the landfill to prevent animals from burrowing into the refuse. Construction of associated gas vents and groundwater monitoring wells, and redevelopment of the golf course holes 6 and 7 were completed as part of the selected remedy (Navy, 2002).

The Site 22 Landfill cover consists (from bottom to top) of a 6-inch foundation layer, a biotic barrier comprised of a 12-inch layer of 4- to 8-inch cobblestone capped with a concrete and sand slurry mix, a 6-inch coarse granular 3/8 pea gravel drainage layer, an 8-ounce geotextile fabric layer, and an 8-inch topsoil layer capped with a 4-inch layer of sand (Tetra Tech FW, Inc. [TtFW], 2003). A subsurface drainage system was installed above the biotic barrier, directing water that infiltrates the upper layers toward outfalls near the northwest corner, northeast corner, and into the water hazards on the south side of the site. Completed topography directs sheet flow water in the same directions, and toward the east.

2.3 GEOLOGY/HYDROGEOLOGY

The following sections describe the regional and local geologic and hydrogeologic settings for the Site 22 Landfill.

2.3.1 Regional Setting

Moffett is located at the northern end of the Santa Clara Valley Basin, approximately 1 mile south of the San Francisco Bay. Regionally, the Santa Clara Valley contains as much as 1,500 feet of interbedded alluvial, fluvial, and estuarine deposits (Iwamura, 1980). Locally, these sediments consist of varying combinations of clay, silt, sand, and gravel that represents the interfingering of estuarine and alluvial depositional environments during the late Pleistocene and Holocene epochs. The fluvial sediments were derived from the Santa Cruz highlands west of the basin and deposited on an alluvial plain bounded by alluvial fan deposits to the west and baylands to the northeast (Iwamura, 1980). The heterogeneous nature of channel and interchannel sediments deposited in the fluvial depositional environment is evident in the many subsurface explorations conducted at Moffett. These sediments most likely were deposited during the Holocene period when the worldwide sea level was rising toward its present elevation.

The subsurface sediments were initially divided into upper and lower aquifers by Iwamura (1980), based on hydrogeologic characteristics. An investigation conducted by Harding Lawson Associates (HLA) (1988) classified these aquifers as the A, B, and C aquifers. The A and B aquifers correspond to Iwamura's upper aquifer, and the C aquifer corresponds to Iwamura's lower aquifer. HLA further subdivided the B aquifer into three subunits (B1, B2, and B3 aquifer zones). International Technology Corporation (IT) reclassified the B1 sediments as the A2 aquifer zone based on lithologic and sedimentologic similarities between the A and B1 materials (IT, 1991). Based on recent studies, TtFW has reclassified the A1 and A2 aquifer zones into the upper and lower portion of the A aquifer, respectively (TtFW, 2005). Aquifer materials within this system range from clays and silts, to fine and medium sands, to coarse gravel. Table 2-1 presents the generalized hydrostratigraphy for Site 22.

TABLE 2-1
HYDROSTRATIGRAPHY, SITE 22
FORMER NAS MOFFETT FIELD

Unit	Unit Subdivision	Range of Approximate Depths (feet bgs)	
		Top	Bottom
A	Upper A (A) aquifer	0 to 15	15 to 35
	Lower A (B1) aquifer	15 to 45	45 to 77
A/B	A/B (A2/B2) aquitard	45 to 65	60 to 85
B	B (B2) aquifer zone	60 to 80	95 to 135
	(B2/B3) aquitard	95 to 105	99 to 111
	B (B3) aquifer zone	99 to 130	115 to 160
B/C	B/C (B3/C) aquitard	115 to 140	155 to 180
C	Unknown/undefined	155 to 160	250
Deep	Unknown/undefined	Generally deeper than 250	

Notes:

The equivalent aquifer/aquitard designations for the MEW sites are in parenthesis.

Abbreviations and Acronyms:

bgs – below ground surface
MEW – Middlefield-Ellis-Whisman
NAS – Naval Air Station

Below the A, B, and C aquifers lie what has been identified as the deep aquifers. Continuous and semi-continuous aquitards divide the aquifers and aquifer zones. The aquifer and aquitard descriptions are based on existing data and lithologic interpretation of soil borings and cone penetrometer tests, as discussed in the *2003 Annual Groundwater Report for WATS and EATS* (TtFW, 2005). The A and B aquifers are currently not used for production purposes, and neither active agricultural nor municipal supply wells are located at Moffett. The C aquifer, however, has historically been used for agricultural purposes at Moffett and as a drinking water source elsewhere in the Santa Clara Valley. There is a continuous confining layer separating the B and underling C aquifers beneath the site and a regional upward hydraulic gradient from the C to the B aquifer. A continuous clay layer has also been observed between the A and underlying B aquifers with regional upward hydraulic gradient from the B aquifer to the A aquifer (TtFW, 2005).

The water table at Moffett is not a static boundary, but fluctuates in response to changes in evaporation, precipitation, and groundwater pumping. The water table at Moffett ranges from approximately 1 to 15 feet below ground surface (bgs). Tidal influence on the elevation of the water table is negligible. Except in the northernmost portion of Moffett, which includes the Site 22 Landfill, the A and B aquifers meet both the State Water Resources Control Board (SWRCB) Resolution 88-63 criteria and U.S. Environmental Protection Agency (EPA) classification guideline criteria for a potential drinking water source.

2.3.2 Local Setting

On a local scale, alluvial processes have juxtaposed clay, silt, sand, and gravel in adjacent depositional environments. The stratigraphy beneath the Site 22 Landfill is thus a complex interfingering of fine- and coarse-grained deposits. Alluvial plain coarse channel deposits are surrounded both laterally and vertically by fine-grained, low-energy interchannel deposits. At Site 22, the vadose zone (between the saturated zone and the land surface) consists primarily of either landfill material or clay and clayey silt. A laterally discontinuous permeable zone has been encountered between 9 and 16.5 feet below mean sea level (msl) (about 9 to 16.5 feet bgs), within the upper A aquifer, and varies in thickness from 1 to 7.5 feet. The thickness of landfill material is as large as 17.5 feet, with the depth of landfill material as large as 10 feet bgs (Navy, 2002). The water table in the area of the site is encountered between 1 foot and 5 feet bgs, so landfill material extends below the local water table.

Groundwater in the area of the Site 22 Landfill is recharged by infiltration from many potential sources, including precipitation (approximately 14 inches annually), golf course irrigation (approximately 17 inches annually), the Northern Channel, and the historic saltwater evaporation ponds now owned by the U.S. Fish and Wildlife Service. A subsurface drainage system was installed above the biotic barrier, directing water that infiltrates the upper layers toward outfalls

near the northwest corner, northeast corner, and into the water hazards on the south side of the site. Completed topography directs sheet flow water in the same direction and toward the east.

Information on local groundwater movement was presented in the *Appendix F Final Post-Construction Operations, Maintenance, and Monitoring Plan* (TtFW, 2003). In general, groundwater elevations appear to show a seasonal trend with highs in February and lows in August. The groundwater flow direction is predominantly to the west with occasional flow directions toward the northwest. Eight rounds of water level elevations were collected from November 2003 through October 2004 (Table 2-2) during the baseline monitoring period, as required by the OMMP (TtFW, 2003). Appendix A includes the potentiometric figures for the eight rounds of groundwater elevations from November 2003 through October 2004. Figure 2-1 shows the potentiometric surface at Site 22 measured in October 2004. The potentiometric surface to the east of the refuse at Site 22 appears to have been altered as a result of the installation of the biotic barrier. Although groundwater continues to flow predominantly to the west, a groundwater divide is interpreted to be located east of the refuse. The location of the hydraulic divide varies slightly (see Appendix A) but is interpreted to always lie east of the refuse (Figure 2-2).

Saltwater intrusion from the north into the Site 22 Landfill area is evident in the analytical results for groundwater samples collected in April 1998 (Tetra Tech EM, Inc. [TtEMI], 1999). Total dissolved solids (TDS) concentrations in groundwater sampled from wells in 1998 surrounding the Site 22 Landfill ranged from 9,500 to 45,000 milligrams per liter (mg/L). The TDS concentrations exceeded the 3,000 mg/L criteria in all of the five samples tested and exceeded the 10,000-mg/L criteria in four of the five samples tested. The groundwater beneath the Site 22 Landfill exceeds both EPA and SWRCB TDS concentrations for a potential drinking water source. SWRCB Resolution 88-63 states that an aquifer is a potential drinking water source if it contains groundwater with a TDS concentration below 3,000 mg/L and a single well can sustain a yield of 200 gallons per day (gpd). EPA guidelines state that an aquifer with a TDS concentration of less than 10,000 mg/L and a yield of 150 gpd may be considered a potential drinking water source. Therefore, groundwater at the Site 22 Landfill is not a potential drinking water source.

The *San Francisco Bay Water Quality Control Plan* (Basin Plan) of 1995 (Regional Water Quality Control Board [RWQCB], 1995) identifies potential and beneficial uses of groundwater in the region. For the Santa Clara Valley Basin, all four beneficial uses of groundwater (municipal/domestic, industrial process, industrial, and agricultural water supply) are listed in the Basin Plan as existing uses. However, at Site 22, none of these is an existing use; although, industrial service supply may be a potential use. Municipal/domestic and agricultural supply are neither existing nor potential uses due to elevated TDS.

TABLE 2-2**BASELINE GROUNDWATER GAUGING DATA FOR SITE 22**

Well	Top of Casing (feet msl)	November 2003		December 2003		February 2004		March 2004		May 2004		July 2004		August 2004		October 2004	
		Depth-to-water (feet)	Groundwater Elevation (feet msl)														
WGC2-1	-2.49	0.80	-3.29	0.20	-2.69	0.00	-2.49	0.16	-2.65	0.80	-3.29	0.89	-3.38	0.99	-3.48	0.25	-2.74
WGC2-4	-0.96	1.55	-2.51	1.54	-2.50	0.90	-1.86	1.38	-2.34	1.73	-2.69	1.98	-2.94	2.10	-3.06	1.55	-2.51
WGC2-5	-0.48	2.30	-2.78	2.09	-2.57	1.90	-2.38	2.05	-2.53	2.45	-2.93	2.57	-3.05	2.82	-3.30	2.19	-2.67
WGC2-6	-1.23	2.78	-4.01	2.65	-3.88	2.35	-3.58	2.79	-4.02	3.00	-4.23	3.25	-4.48	3.45	-4.68	3.41	-4.64
WGC2-8	-1.03	2.62	-3.65	2.00	-3.03	2.00	-3.03	2.32	-3.35	2.65	-3.68	2.49	-3.52	2.77	-3.80	2.33	-3.36
	-1.37	2.90		1.95	-3.32	1.18	-2.55	-4.27	#REF!	2.35	-3.72	2.52	-3.89	2.57	-3.94	2.11	-3.48
WGC2-10	-2.20	1.30	-3.50	0.80	-3.00	0.03	-2.23	0.95	-3.15	1.27	-3.47	1.57	-3.77	1.58	-3.78	1.04	-3.24
WGC2-11	-2.52	0.80	-3.32	0.80	-3.32	0.00	-2.52	0.35	-2.87	0.11	-2.63	1.10	-3.62	1.13	-3.65	0.59	-3.11
WGC2-12	0.58	3.37	-2.79	2.60	-2.02	2.85	-2.27	2.99	-2.41	3.29	-2.71	3.53	-2.95	3.75	-3.17	3.23	-2.65
WGC2-13	-0.76	1.98	-2.74	1.44	-2.20	0.75	-1.51	1.35	-2.11	1.90	-2.66	2.27	-3.03	2.35	-3.11	1.66	-2.42

Notes:

Survey coordinates as measured 12/11/03 and 12/17/03.

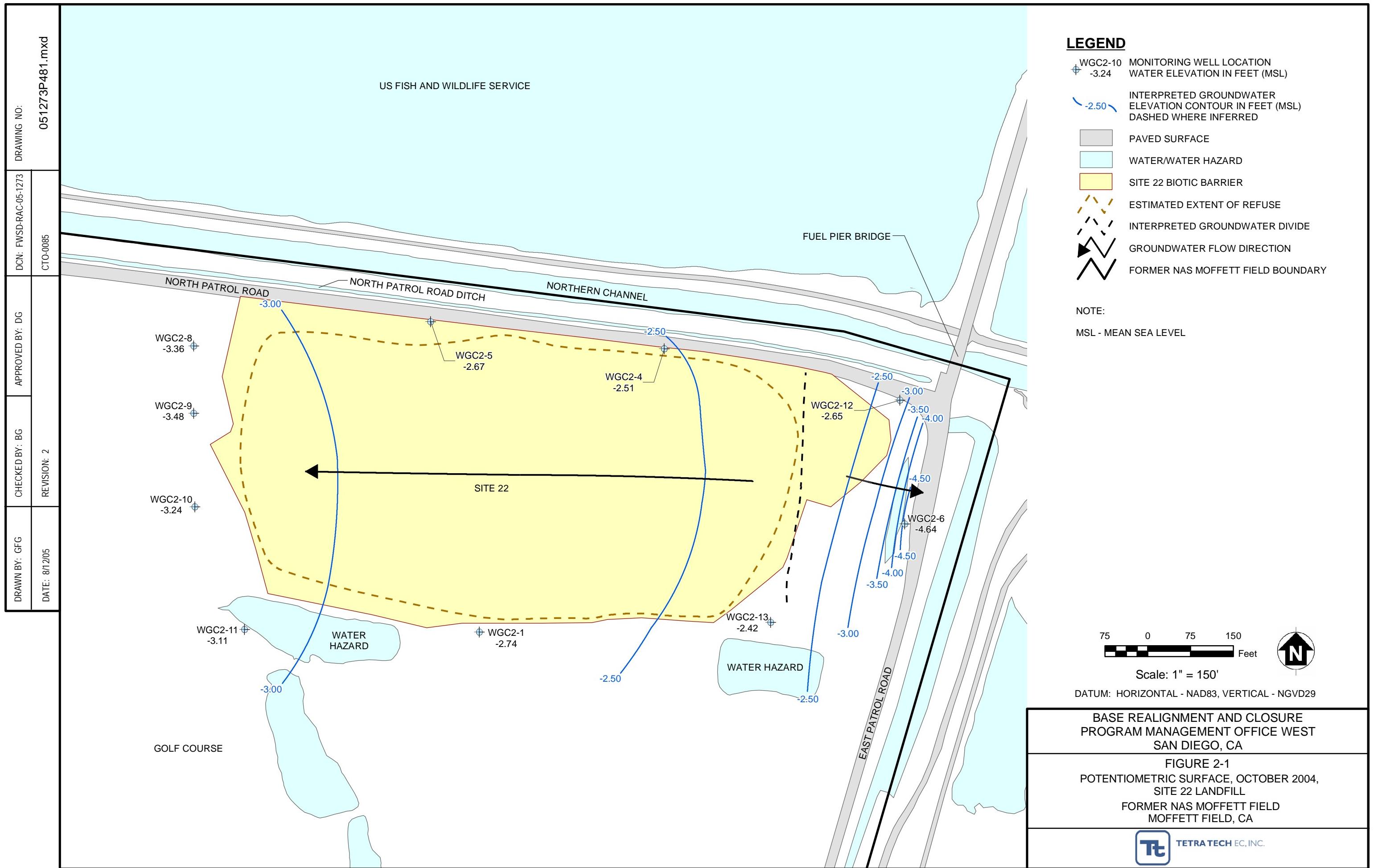
Coordinates are California Coordinate System North American Datum 83, Zone 3, U.S. Survey Feet.

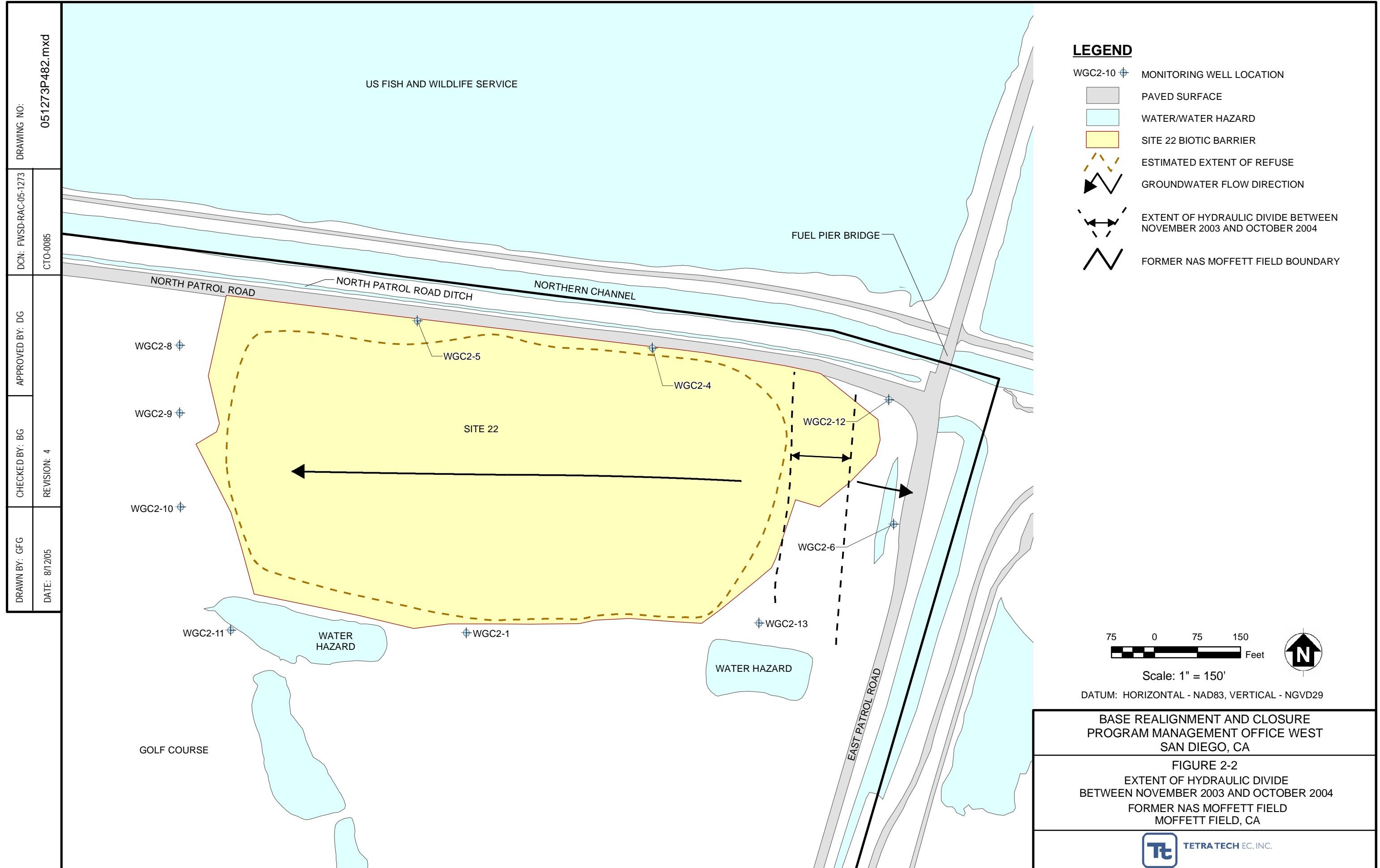
Elevations are National Geodetic Vertical Datum 29 U.S. Survey Feet.

Positions determined using National Aeronautics and Space Administration Ames Research Center (ARC) Control Monument ARC-34.

Abbreviations and Acronyms:

msl - mean sea level





2.3.3 Surface Water and Groundwater

There are four surface water bodies within the vicinity of the Site 22 Landfill: the Northern Channel, historic evaporation ponds now owned by the U.S. Fish and Wildlife Service, North Patrol Road Ditch to the north, and the golf course water hazards to the south and east. According to the RWQCB Basin Plan (1995), the beneficial uses for surface water near the site are freshwater/estuarine habitat and wildlife habitat. The hydraulic relationships between surface water and groundwater are discussed in the following paragraphs.

The stratigraphy in the area of the Site 22 Landfill consists predominantly of clay and silty clay with discontinuous sand and silt intervals. Because of the discontinuous sand and silt intervals, communication between groundwater and surface water is limited. Hydraulic communication between groundwater and any surface water is impeded by the relatively low hydraulic conductivity of clay/silty clay. There does not appear to be a direct permeable flow pathway between the groundwater and nearby surface water. In addition, the Site 22 biotic barrier (see Section 2.2) further decreases the potential for precipitate infiltration and directs surface water away from the site.

There appears to be only limited communication between groundwater and North Patrol Road Ditch. The North Patrol Road Ditch is a surface drainage feature that carries a portion of surface stormwater flow from the eastern side of Moffett. During times of low stormwater runoff, there is little or no water in the ditch east of Marriage Road and in the North Patrol Ditch to the north of the golf course. The lack of base flow in the ditches in the absence of stormwater runoff indicates that little or no groundwater discharges to the ditches. Lithology of water bearing materials penetrated by the ditches is the same relatively impermeable clay and clayey silt beneath the site. Hydraulic communication between groundwater and the ditch is impeded by the relatively low hydraulic conductivity of clay/silty clay (Navy, 2002).

2.4 EXPOSURE PATHWAY ANALYSIS AND RECEPTORS

An exposure pathway analysis links the sources, locations, and types of environmental releases with population locations and activity patterns to determine whether significant pathways exist for human or ecological exposure (EPA, 2003). Complete exposure pathways occur when constituents of concern have a source and mechanism which enable a release to the environment, an environmental transport medium, a point of receptor contact with the contaminated media, and an exposure route. For aquatic organisms, exposure routes include direct contact with water or sediments, and ingestion of food or sediments (EPA, 1997a). Complete exposure routes for humans and higher trophic level organisms include dermal contact with water or sediment and ingestion of affected organisms.

2.4.1 Exposure Pathways

The primary exposure pathway for groundwater downgradient from the Site 22 Landfill is by discharge to the Northern Channel through the operation of Building 191. There are no known intervening seeps, springs, or marshy areas that could lead to exposure to human or terrestrial receptors. The North Patrol Road Ditch is not considered an exposure pathway because it is not interpreted to be in hydrogeologic connection with the upper portion of the A aquifer. The flow in the North Patrol Road Ditch is intermittent and dependent on surface water drainage from the Marriage Road Ditch located west of Site 22. The nearby water hazards at the Site 22 golf course are not interpreted to be hydraulically connected to the shallow aquifer due to the fine-grained silts and clays at the surface.

The North Patrol Road Ditch consists of freshwater (surface water drainage). The Northern Channel is a eutrophic, brackish-water system with groundwater and stormwater input from Building 191 (PRC Environmental Management [PRC] and J.M. Montgomery, 1992). The Northern Channel is believed to undergo shifts in seasonal levels of salinity. The salinity of the Northern Channel ranges from approximately 7 to 15 parts per thousand (ppt), a measurement indicative of a brackish water habitat common in estuaries and salt marshes (PRC and J.M. Montgomery, 1992). The RWQCB states that saltwater criteria shall apply to surface waters with salinities greater than 10 ppt during 95 percent of the normal water year (RWQCB, 2000).

2.4.2 Human Receptors

Direct human exposure to groundwater at Site 22 is unlikely for the following reasons:

- There are no local wells or known natural seeps or springs where water could be withdrawn for local consumption.
- The shallow aquifer underlying Site 22 does not supply water to local or municipal wells.
- The groundwater is not considered potable for human or animal consumption because it does not meet the state standards for TDS (less than 3,000 mg/L) (Navy, 2002).
- High TDS concentration precludes its use for beneficial use.

Chemicals in groundwater that might be discharged to surface water could affect humans indirectly via accumulation in edible aquatic organisms; however, this possibility is unlikely in the Northern Channel. In general, the brackish-water fish and invertebrates in the potential receiving water body are unlikely to be consumed as part of recreational use, personal use, or a subsistence fishery because they are small and undesirable² and because fences restrict access to

² Two species of fish have been identified in the Northern Channel. Neither is considered desirable for consumption. Mosquito fish (*Gambusia affinis*) is a very small species of fish that Mosquito Abatement Districts stock in drainage ditches, lagoons, and small ponds to control mosquito populations. The longjaw mudsucker (*Gillichthys mirabilis*) is a bottom-dwelling, brackish-water fish.

the Northern Channel (PRC, 1996). There are no known complete exposure pathways to human exposure.

2.4.3 Ecological Receptors

The primary potential receptors are aquatic organisms associated with surface water in the Northern Channel. Aquatic organisms are treated as primary receptors because they could have an immediate, direct, and continuous exposure by way of a primary uptake route (direct contact). Higher trophic level birds and mammals could be exposed to chemicals discharged to surface water by dermal contact, ingestion of water, and ingestion of secondary contaminated media, such as food or sediments. In general, risks to higher trophic level organisms by dermal contact or ingestion of water are negligible. Rather, these organisms are primarily affected by chemical accumulation in food or sediments (TtEMI, 2000).

The Northern Channel has an unconsolidated bottom sitting on impermeable clays and silts (TtEMI, 2000). Habitat such as that found in the Northern Channel supports dense growth of green and blue-green algae, which may, in turn, support populations of invertebrates and intertidal fish. The Northern Channel supports several fish and epibenthic invertebrate species, including bay shrimp, crabs, mosquito fish, and longjaw mudsuckers (TtEMI, 2000).

Chemicals in groundwater discharged into the Northern Channel could affect aquatic organisms through direct exposure and uptake. To assess this possibility, risk-based ecological screening values for aquatic receptors were derived, as explained in Section 4.1.

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3.0 GROUNDWATER SAMPLING RESULTS

Groundwater samples have been collected at Site 22 intermittently from September 1994 through April 1998, and regularly during the baseline monitoring period (November 2003 through October 2004). The purpose of this section is to present a summary of the groundwater sampling results at the Site 22 Landfill for data collected from September 1994 through October 2004. Table 3-1 presents a summary of the constituents of concern (COCs) detected at Site 22 since September 1994.

3.1 MONITORING WELLS SAMPLED

Monitoring wells sampled at Site 22 during the baseline monitoring period are shown on Figure 3-1. As described in Section 2.0, groundwater at Site 22 flows predominantly toward the west and is influenced by the operation of Building 191 (Department of the Navy [Navy], 2002). In 1994 through 1998, sampling was limited to groundwater from monitoring wells WGC2-1 through WGC2-6, as the other monitoring wells (WGC2-8 through WGC2-13) had not yet been constructed. Sampling of groundwater from monitoring wells WGC2-8 through WGC2-13 began in November 2003, as required by the *Appendix F Final Post-Construction Operations, Maintenance, and Monitoring Plan* (Tetra Tech FW, Inc. [TtFW], 2003). This baseline monitoring period was completed to develop a statistically valid data set to determine concentrations and trends of the COCs and water levels.

3.2 ANALYTICAL RESULTS

The following sections briefly describe the groundwater results for the COCs by analytical group [e.g., volatile organic compounds (VOCs), pesticides, and semivolatile organic compounds (SVOCs)] from September 1994 to October 2004. Appendix B provides summary tables (B-1 through B-3) showing the COCs detected above the method detection limit³ (MDL) during the baseline monitoring period from November 2003 through October 2004. Those analytes detected below the sample quantitation limit⁴ (SQL) (also called the reporting level [RL]) are flagged with a “J” qualifier, designating estimated values. Table 3-1 identifies the month and year sampled, well number, concentration detected, and number of times (n) the analyte has been detected. Table 3-1 illustrates the sporadic nature of COC detections at the site.

³ The MDL is the lowest quantity of a chemical that can be detected by a laboratory under ideal conditions. It is based on the signal-to-noise ratio. The MDL is based on a spike of laboratory grade water. MDL does not consider matrix interferences.

⁴ The SQL (also called the RL) represents the chemical concentration that can be reliably and reproducibly detected. It takes into account matrix interferences and is what is achievable by a laboratory using field samples. Samples with no detectable concentrations lower than the MDL have a “U” qualifier. Sample concentrations between the SQL and the MDL are estimated, and have a “J or B” qualifier.

3.2.1 VOCs

VOCs were detected sporadically in samples from groundwater monitoring wells at Site 22. The VOCs detected above the MDLs (see Table 3-1) include the following:

- Benzene (3)
- Chloroform (13)
- Trichloroethene (TCE) (19)
- cis-1,2-Dichloroethene (5)
- Toluene (7)

Groundwater samples collected in 1994 and 1995 show estimated detections of benzene, chloroform, and toluene. With the exception of chloroform and a single detection of toluene (November 2003), these analytes have not been detected again. The detections of cis-1,2-DCE, chloroform, and TCE were consistent in concentration and location (WGC2-8 and WGC2-9, both downgradient wells). Cis-1,2-DCE is a degradation product of TCE. Chloroform is often found as an impurity in TCE.

3.2.2 Pesticides

Pesticides were detected during one sampling round (November 2003) at Site 22 (see Table 3-1). The detections include aldrin (2) and gamma-benzene hexachloride (BHC) (Lindane) (3). Of the five detections of pesticides, three were estimated concentrations (“J” flagged) during November 2003 in samples collected from downgradient monitoring well WGC2-9 (aldrin and gamma-BHC [Lindane]), and in samples collected from cross-gradient monitoring well WGC2-12 (gamma-BHC). The detections were just above the RL in November 2003 in samples from downgradient monitoring well WGC2-11. The remaining sampling rounds during the baseline monitoring period showed no concentrations of pesticides above the method RL.

3.2.3 SVOCs

Bis(2-ethylhexyl)phthalate (BeP) has been detected twice in samples from groundwater monitoring wells at Site 22 (see Table 3-1). BeP was detected in a sample from cross-gradient monitoring well WGC2-5 in April 1998 at a concentration of 15 micrograms per liter ($\mu\text{g}/\text{L}$) and in a sample from reference monitoring WGC2-6 in September 2004 at an estimated concentration of 11J $\mu\text{g}/\text{L}$. BeP is a common plasticizer and laboratory contaminant.

TABLE 3-1

**FREQUENCY AND LOCATION OF COCs DETECTED AT SITE 22
SEPTEMBER 1994 THROUGH OCTOBER 2004**

Analyte	Sep-94	Nov-94	Mar-95	Jun-95	Apr-98	Nov-03	Dec-03	Feb-04	Mar-04	May-04	Jul-04	Sep-04	Oct-04
VOCs													
Benzene n = 3	<u>WGC2-1</u> 0.2 J				<u>WGC2-5</u> 0.08 J								
Chloroform n = 13	<u>WGC2-4</u> 0.5 J					<u>WGC2-4</u> 1.2 <u>WGC2-8</u> 0.97 J <u>WGC2-9</u> 6.7 <u>WGC2-13</u> 0.35 J	<u>WGC2-9</u> 3.7	<u>WGC2-9</u> 7.0 <u>WGC2-13</u> 0.22 J	<u>WGC2-9</u> 5.4	<u>WGC2-9</u> 5.1	<u>WGC2-9</u> 3.8	<u>WGC2-9</u> 3.7	<u>WGC2-9</u> 3.7
cis-1,2-Dichloroethene n = 5					<u>WGC2-8</u> 0.27 J		<u>WGC2-8</u> 0.24 J	<u>WGC2-8</u> 0.21 J	<u>WGC2-8</u> 0.23 J			<u>WGC2-8</u> 0.22 J	
Toluene n = 7	<u>WGC2-1</u> 0.2 J <u>WGC2-5</u> 2 J <u>WGC2-4</u> 0.3 J <u>WGC2-6</u> 0.2 J	<u>WGC2-5</u> 0.2 J			<u>WGC2-5</u> 0.1 J		<u>WGC2-13</u> 0.22 J						

TABLE 3-1

**FREQUENCY AND LOCATION OF COCs DETECTED AT SITE 22
SEPTEMBER 1994 THROUGH OCTOBER 2004**

Analyte	Sep-94	Nov-94	Mar-95	Jun-95	Apr-98	Nov-03	Dec-03	Feb-04	Mar-04	May-04	Jul-04	Sep-04	Oct-04
Trichloroethene n = 19			<u>WGC2-4</u> 0.4 J		<u>WGC2-6</u> 0.6 J	<u>WGC2-6</u> 10 J							
Xylene (Total) n = 1	<u>WGC2-5</u> 2 J												
<i>Pesticides</i>													
Aldrin n = 2						<u>WGC2-9</u> 0.036 J							
gamma-BHC (Lindane) n = 3						<u>WGC2-9</u> 0.042 J							
						<u>WGC2-11</u> 0.1							
						<u>WGC2-11</u> 0.2							
						<u>WGC2-12</u> 0.022 J							
<i>SVOCs</i>													
bis(2-Ethylhexyl)phthalate n = 2					<u>WGC2-5</u> 15						<u>WGC2-6</u> 11 J		

Notes:

All concentrations in µg/L.

Abbreviations and Acronyms:

µg/L - micrograms per liter

BHC - benzene hexachloride

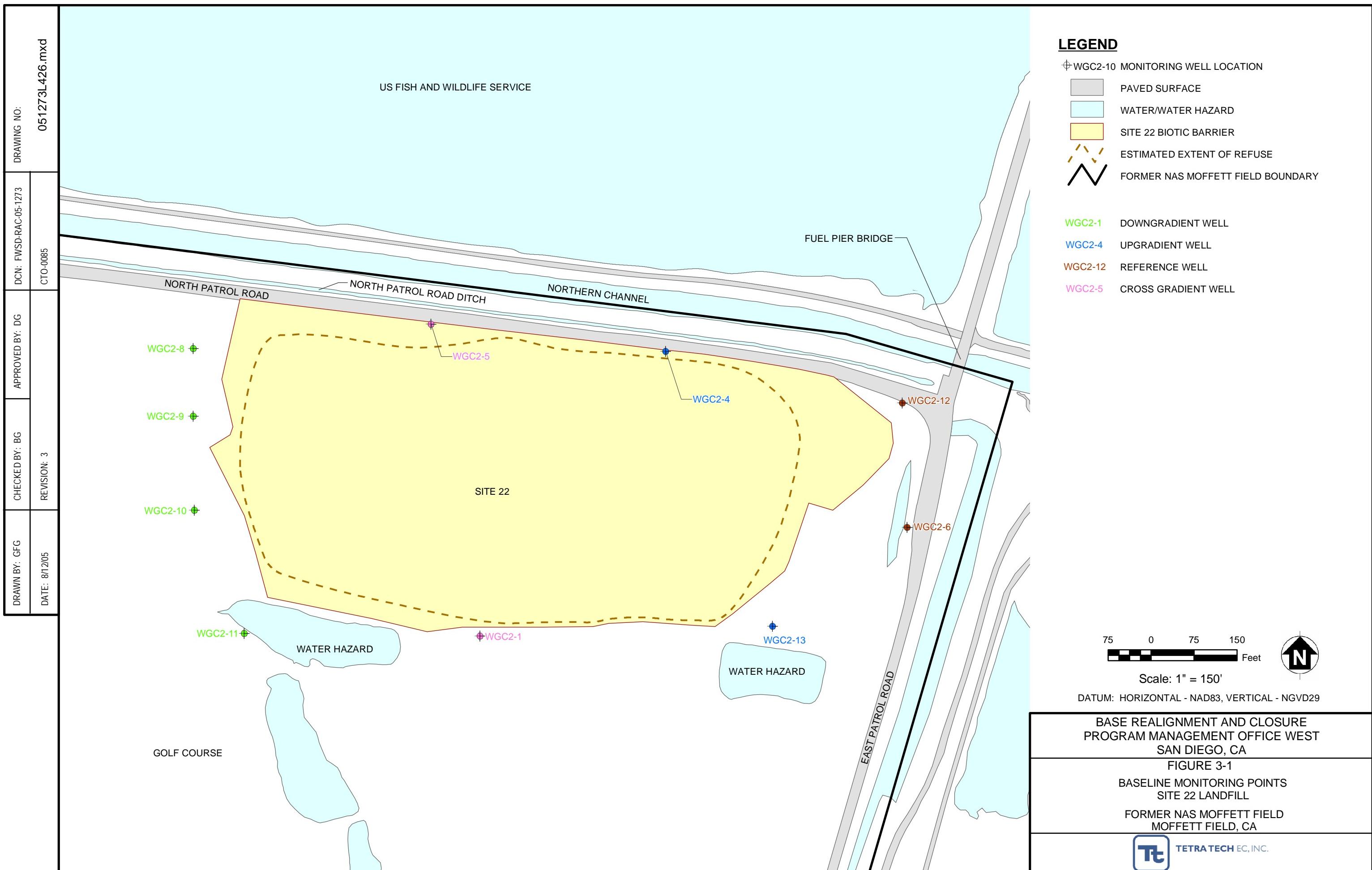
COC - constituent of concern

J - Estimated value

K - unspecified data qualifier from previous contractor

SVOC - semivolatile organic compound

VOC - volatile organic compound



4.0 GROUNDWATER DETECTION MONITORING PROGRAM

The purpose of the groundwater detection monitoring program is to evaluate the groundwater conditions at the site in accordance with the requirements of the Record of Decision (ROD) and Title 27. This section describes elements of the proposed groundwater detection monitoring program, which includes the calculated concentration limits (CCLs), monitoring points, the point of compliance (POC), the groundwater data evaluation process, the monitoring parameters (MPs), and monitoring frequency.

4.1 CALCULATED CONCENTRATION LIMITS

The ROD (Department of the Navy [Navy], 2002) requires the Navy to develop a groundwater monitoring program that will incorporate the substantive provisions of portions of Title 27, Subchapter 3 (see Section 1.2.1). Part of the groundwater monitoring program includes the development of concentration limits for constituents of concern (COCs) at Site 22. The COCs, as specified in the ROD, are presented in Table 1-1. The CCLs proposed are based on the exposure pathways (see Section 2.4) and potential groundwater use at the site (see Section 2.3.2). Applicable screening criteria were selected to develop the concentration limits.

Ambient water quality criteria (AWQCs) and other appropriate surface water screening criteria were considered to be protective of aquatic organisms and applicable for Site 22 based on the exposure pathways. Concentration limits must relate surface water screening value criteria to groundwater sample results; therefore, it was necessary to develop and apply an attenuation factor (AF). An AF accounts for the natural groundwater processes (i.e., advection-dispersion, sorption, and degradation) that have an impact on each COC. CCLs will be used in the evaluation of groundwater data collected from the monitoring points, as prescribed by the ROD.

The following sections describe the derivation process for the site-specific screening values, calculation of the AFs, and the derivation of the CCLs for groundwater. This approach is consistent with the approach approved by the U.S. Environmental Protection Agency (EPA) and the San Francisco RWQCB at the Moffett Site 1 Landfill (Tetra Tech FW, Inc. [TtFW], 2004).

4.1.1 Basis for Identifying Surface Water Screening Values

Preference for screening values was given to chronic saltwater criteria. Chronic criteria were given priority because these are most protective of reproduction and the long-term health of aquatic populations at the point of exposure (POE), whereas acute values are based on short-term exposures of high analyte concentrations. Saltwater values are more appropriate because of the brackish nature of the Northern Channel. EPA or California chronic saltwater criteria do not exist for any of the Site 22 COCs; therefore, a protocol was developed for deriving chronic

saltwater values from other sources of surface water. The hierarchy used is summarized in Table 4-1.

Since EPA or California saltwater chronic criteria also do not exist, chronic saltwater values from National Oceanic and Atmospheric Administration (NOAA) were used, if available. The NOAA Screening Quick Reference Tables (SQuiRT™) (NOAA, 1999) were developed by NOAA's Coastal Protection and Restoration Division as a tool for identifying potential impacts to coastal resources and habitats that could be affected by hazardous waste sites. For surface waters, NOAA's SQuiRT™ screening values are based on acute and chronic values for both saltwater and freshwater, and are generally equal to or more stringent than the EPA and California values.

If a NOAA saltwater chronic value was not identified, a saltwater acute value, with an appropriate safety factor (SF), was used. The saltwater acute value was divided by a SF of 10 to estimate a saltwater chronic value (RWQCB, 2001; EPA, 1997b). This approach is consistent with the SF of 10 that the RWQCB used in *Application of Risk-Based Screening Levels and Decision Making to Sites with Impacted Soil and Groundwater* (RWQCB, 2001) to derive groundwater screening levels from acute criteria. A SF of 10 for acute to chronic extrapolation has also been cited in other ecological risk assessment guidance, such as EPA Region 8's *Uncertainty Factor Protocol for Ecological Risk Assessment, Toxicological Extrapolations to Wildlife Receptors* (EPA, 1997a). Acute saltwater values from EPA and California were given preferences; then NOAA criteria were used as required in the order of preference shown in Table 4-2.

If a saltwater value was not available, freshwater values were used. No EPA, state, or other guidance exists for applying freshwater values to saltwater environments; however, several papers in the literature address this issue. Hutchinson et al. (1998) showed that the sensitivity of freshwater and saltwater fish was within a factor of 10 for 91 and 93 percent of the chemicals evaluated based on acute and chronic studies, respectively. These results support the use of a SF of 10 (converting from freshwater to saltwater criteria by dividing freshwater values by 10) to be protective of saltwater species. A SF of 10 was used in this evaluation. Freshwater values from Oak Ridge National Laboratory (ORNL) (ORNL, 1996) were used, based on the hierarchy in Table 4-1. The ORNL screening values are based on a compilation of a variety of toxicological endpoints for aquatic receptors in freshwater habitats. ORNL's procedure identifies a range of toxicological benchmarks for each chemical reviewed, including acute and chronic toxicity values.

The saltwater and freshwater criteria and screening values available from EPA, California EPA, NOAA, and ORNL are summarized in Table 4-2. The table shows the lack of EPA and California AWQC for most of the COCs.

TABLE 4-1

**HIERARCHY FOR DERIVING CHRONIC SALTWATER
SCREENING VALUES FOR SURFACE WATER, SITE 22
FORMER NAS MOFFETT FIELD**

1. NOAA ^(c) chronic saltwater values.
2. EPA ^(a) /California ^(b) AWQC acute saltwater criteria. Acute saltwater criteria were divided by an SF of 10 in order to be protective of chronic exposures.
3. NOAA ^(c) acute saltwater values. Acute saltwater values were divided by an SF of 10 in order to be protective of chronic exposures.
4. ORNL ^(d) lowest available chronic freshwater values. Chronic freshwater values were divided by a SF of 10 in order to be protective in saltwater environments.
5. Surrogate chemical based on availability of an isomer, homomorph, or toxicity and chemical properties, and a surrogate value was selected using the approach in steps 1 to 4.

Abbreviations and Acronyms:

AWQC – ambient water quality criteria

EPA – U.S. Environmental Protection Agency

NAS – Naval Air Station

NOAA – National Oceanic and Atmospheric Administration

ORNL – Oak Ridge National Laboratory

SF – safety factor

Sources:

(a) EPA, 1999

(b) EPA, 2000

(c) NOAA, 1999

(d) ORNL, 1996

TABLE 4-2

SCREENING VALUES FOR CONSTITUENTS OF CONCERN, SITE 22
FORMER NAS MOFFETT FIELD

COC ^(a)	EPA AWQC (µg/L) ^(b)						California AWQC (µg/L) ^(c)						NOAA SQuiRT™ (µg/L) ^(d)						Oak Ridge National Laboratory (µg/L) ^(e)		
	Freshwater			Saltwater			Freshwater			Saltwater			Freshwater			Saltwater			Freshwater		
	Acute	Chronic	Notes	Acute	Chronic	Notes	Acute	Chronic	Notes	Acute	Chronic	Notes	Acute	Chronic	Notes	Acute	Chronic	Notes	Acute	Chronic	Notes
VOCs																					
Benzene	--	--	--	--	--	--	--	--	--	--	--	--	5,300	--	b	5,100	700	b	2,300	130	a
Chlorobenzene	--	--	--	--	--	--	--	--	--	--	--	--	250	50	b,c	160	129	b,c	1,100	64	a
Chloroform	--	--	--	--	--	--	--	--	--	--	--	--	28,900	1,240	b	--	--	--	490	28	a
cis-1,2-Dichloroethene ^(f)	--	--	--	--	--	--	--	--	--	--	--	--	11600	--	b	224000	--	b	1,100	590	a
Ethylbenzene	--	--	--	--	--	--	--	--	--	--	--	--	32,000	--	b	430	--	b	130	7.3	--
Toluene	--	--	--	--	--	--	--	--	--	--	--	--	17,500	--	b	6,300	5,000	b	120	9.8	a
Trichloroethylene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	440	47	a
Vinyl chloride ^(f)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1,100	590	a
Xylene (total) ^(g)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	32	1.8	--
Pesticides																					
Aldrin	3	--	--	1.3	--	--	3	--	--	1.3	--	--	1.5	--	c	0.65	--	c	--	--	
gamma-BHC (Lindane)	0.95	--	--	0.16	--	--	0.95	--	--	0.16	--	--	0.95	0.08	--	0.08	--	c	2	0.08	--
SVOCs																					
1,4-Dichlorobenzene	--	--	--	--	--	--	--	--	--	--	--	--	1,120	763	b	1,970	129	b,c	180	15	a
2-Methylnaphthalene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	300	--	b,c	--	--	
4-Methylphenol ^(h)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	230	13	--
bis(2-Ethylhexyl)phthalate	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	27	3	a
Carbazole ⁽ⁱ⁾	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	66	3.7	a
Dibenzofuran	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	66	3.7	a
Diethylphthalate	--	--	--	--	--	--	--	--	--	--	--	--	940	3	b,c	2,944	3.4	b,c	1,800	210	a
Fluorene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	300	--	b,c	70	3.9	a
Naphthalene	--	--	--	--	--	--	--	--	--	--	--	--	2,300	620	b	2,350	--	b	190	12	a

Notes:

Notes are divided into two categories for the reader's ease in understanding. The two categories are COCs (represented by alpha designations in parentheses) and Screening Criteria (represented by alpha designations).

COCs:

(a) COCs that did not appear in any of the four criteria sources were assigned surrogates. Surrogates were chosen based on the criteria described in Section 4.1.1.

(b) EPA AWQC values taken from *National Recommended Water Quality Criteria--Correction*, EPA, April 1999. All values are based on dissolved metals, unless otherwise noted.

(c) California EPA AWQC values were obtained from the Federal Register, Vol. 65, No. 97, May 18, 2000.

(d) SQuirt™ was compiled by NOAA's Office of Response and Restoration.

(e) Values were taken from *Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision*, from the ORNL.

AWQC values for acute and chronic toxicity were used, unless otherwise noted.

(f) 1,2-Dichloroethene was used as a surrogate.

(g) m-Xylene was used as a surrogate.

(h) 2-Methylphenol was used as a surrogate.

(i) Dibenzofuran was used as a surrogate.

Screening Criteria:

^a Tier II Secondary Values for protection of aquatic life are used for this analyte. Tier II values were developed so that aquatic benchmarks could be established with fewer data than required by the AWQC.

They were derived by the method described in EPA's *Proposed Water Quality Guidance for the Great Lakes System* (EPA, 1993).

^b This is the lowest observable effect level (not a criterion).

^c CMC has been halved to be comparable to criteria derived by 1985 Guidelines.

TABLE 4-2

**SCREENING VALUES FOR CONSTITUENTS OF CONCERN, SITE 22
FORMER NAS MOFFETT FIELD**

Abbreviations and Acronyms:

µg/L – micrograms per liter
 AWQC – ambient water quality criteria
 BHC – benzene hexachloride
 CMC – criterion maximum concentration
 COC – constituent of concern
 EPA – U.S. Environmental Protection Agency
 NAS – Naval Air Station
 NOAA – National Oceanic and Atmospheric Administration
 ORNL – Oak Ridge National Laboratory
 SQuirtTM – Screening Quick Reference Tables
 SVOC – semivolatile organic compound
 VOC – volatile organic compound
 -- – no value reported

If there were no EPA, California AWQC, NOAA, or ORNL COC-specific screening criteria available, a surrogate chemical was identified, and its screening value was used. The industry standard practice is to select a surrogate chemical for a COC based on similarities in chemical structure, chemical properties, and potential aquatic toxicity. The underlying premise of this industry standard practice is that chemical structure and toxicity are highly correlated. Factors such as the number of bonds, numbers and types of functional groups, and the number of aromatic rings affect the absorption, metabolism, and, ultimately, the toxicity of an analyte. The process is described below:

1. Does the COC have an isomer with a screening value? If so, the reported isomer was used as a surrogate for the COC (e.g., 1,2-dichloroethene [DCE] is used as a surrogate for cis-1,2-DCE).
2. Does the COC have a homomorph (compounds that are structurally similar)? If so, the homomorph was used as a surrogate (i.e., 1,2-DCE is used as a surrogate for vinyl chloride). If there was more than one homomorph to consider, the screening criteria and EPA's ECOSAR⁵ program (EPA, 2001) were reviewed to compare the aquatic toxicity data for the COC and the potential surrogates, if available.

During the development of the screening values, surrogates were used for five COCs (see Table 4-2). Appendix C provides the explanation behind each surrogate selected and its applicability. Table 4-3 presents the chronic saltwater screening value used for each COC at Site 22 and the source of each value.

4.1.2 Attenuation Factors

It is not appropriate to compare groundwater concentrations directly to surface water screening values due to the physical and chemical processes (dispersion, sorption, and degradation) that take place in groundwater before it discharges to surface water. Consequently, AFs were developed to account for changes in groundwater chemistry due to site- and chemical-specific conditions during seepage of groundwater from Site 22 monitoring wells to the closest possible surface water discharge location. Appendix D presents the details regarding the development of the AFs.

AFs were developed using the EPA-accepted Analytical Transient 1-, 2-, 3-Dimensional (AT123D) fate-and-transport model (Yeh, 1981). The analytical results from each model run were compared to results from BIOCHLOR, a model developed by the EPA (EPA, 2000) that uses an analytical solution for chemical transport, based on the Domenico analytical solute

⁵ The ECOSAR program is based on the concept of structural activity relationships, and it provides predicted aquatic toxicity data for chemicals based on their structural similarities to chemicals for which aquatic toxicity data are available.

transport model (Domenico and Schwartz, 1987). Both solutions (AT123D and BIOCHLOR) gave comparable results.

Site- and chemical-specific parameters were used for each run of the model to predict what the concentration of a particular analyte would be at the closest POE (described in Section 2.0 as the Northern Channel) from the closest monitoring well (monitoring well WGC2-8). A conservative distance of 250 feet was used, representing the modeled distance from monitoring well WGC2-8 to the POE. This modeled distance represents about a 45-degree angle to the groundwater flow direction from monitoring well WGC2-8 to the Northern Channel (the distance along the groundwater flow path would be about 500 feet if there was some discharge to Marriage Road ditch and about 1,300 feet if discharge was to the Northern Channel) (Figure 4-1). A simulation time of 105 years was used. This represents the 55 years since the Site 22 Landfill began operation plus 50 years of future monitoring.

The site-specific conditions show that the shallow aquifer beneath Site 22 is dominated by fine-grained clays and silts (Section 2.3) that typically have hydraulic conductivities in the 10^{-6} to 10^{-8} range (Freeze and Cherry, 1979). There is, however, a possibility of sandy lenses occurring within the fine-grained deposits. To be conservative, therefore, a hydraulic conductivity four orders-of-magnitude larger was used (10^{-2} centimeters per second [cm/sec]).

Chemical-dependent values (the soil-water partitioning coefficient [K_{oc}] and half-lives) were chosen using the hierarchical method shown in Table D.4-1, Appendix D. Priority was given to EPA published data. If a range of values was encountered, the value yielding the most conservative (highest concentration) result was selected. Consequently, the lowest value in a range of values for K_{oc} was chosen, while the longest half-life in the range was selected.

Model results predict that, due to naturally occurring processes (dispersion, sorption, and degradation), some analytes never reach the closest POE. This outcome is indicated by a numerical concentration value of zero, or a concentration ratio of “infinite” (Table 4-4). To be conservative, a maximum default AF of 100 was assigned to these analytes. For example, the model predicts that Aldrin will never reach the POE (infinite concentration ratio); therefore, the AF assigned to Aldrin is 100. In addition, all concentration ratios greater than 100 were assigned the maximum default AF value of 100. This represents a conservative position, but accounts for uncertainty in input parameters in the model (a detailed discussion of variability in natural hydrogeologic site conditions and in compound-specific degradation characteristics is provided in Appendix D). Model results predict that other analytes may reach the POE, but at lesser concentrations. For example, the model predicts that benzene will reach the POE at a concentration ratio of 25.7; therefore, the AF assigned to benzene is 25.7.

Uncertainty results from the simplifying assumptions inherent in the models used. Additional uncertainties result from the random nature of real systems, sample measurement error, and the

TABLE 4-3
**DERIVATION OF CHRONIC SALTWATER VALUES FOR CONSTITUENTS OF CONCERN, SITE 22
FORMER NAS MOFFETT FIELD**

COC^(a)	Selected Surface Water Value^(b) (µg/L)	Source of Selected Surface Water Value	Calculated Saltwater Chronic Based on Saltwater Acute (µg/L)	Calculated Saltwater Chronic Based on Freshwater Chronic (µg/L)	Chronic Saltwater Value^(c) (µg/L)
VOCs					
Benzene	700	NOAA-sw,ch	--	--	700
Chlorobenzene	129	NOAA-sw,ch	--	--	129
Chloroform	28	ORNL-fw,ch	--	2.8	2.8
cis-1,2-Dichloroethene ^(d)	590	ORNL-fw,ch	--	59	59
Ethylbenzene	430	NOAA-sw,ac	43	--	43
Toluene	5,000	NOAA-sw,ch	--	--	5,000
Trichloroethene	47	ORNL-fw,ch	--	4.7	4.7
Vinyl chloride ^(d)	590	ORNL-fw,ch	--	59	59
m,p-Xylene ^(e)	1.8	ORNL-fw,ch	--	0.18	0.18
Pesticides					
Aldrin	1.3	EPA-sw,ac	0.13	--	0.13
gamma-BHC (Lindane)	0.16	EPA-sw,ac	0.016	--	0.016
SVOCs					
1,4-Dichlorobenzene	129	NOAA-sw,ch	--	--	129
2-Methylnaphthalene	300	NOAA-sw,ac	30	--	30
4-Methylphenol ^(f)	13	ORNL-fw,ch	--	1.3	1.3
bis(2-Ethylhexyl)phthalate	3	ORNL-fw,ch	--	0.3	0.3
Carbazole ^(g)	3.7	ORNL-fw,ch	--	0.37	0.37
Dibenzofuran	3.7	ORNL-fw,ch	--	0.37	0.37
Diethylphthalate	3.4	NOAA-sw,ch	--	--	3.4
Fluorene	300	NOAA-sw,ac	30	--	30
Naphthalene	2,350	NOAA-sw,ac	235	--	235

Notes:

- (b) Selected surface water value was determined using the hierarchy for Site 22 as described in Table 4-2 and Section 4.1.1.
 (c) Saltwater chronic value was derived by applying a safety factor of 10 if the most appropriate criteria available were saltwater acute or freshwater chronic values.
 (d) 1,2-Dichloroethene was used as a surrogate.
 (e) m-Xylene was used as a surrogate.
 (f) 2-Methylphenol was used as a surrogate, reported as 3/4-methylphenol by analytical laboratory.
 (g) Dibenzofuran was used as a surrogate.

Abbreviations and Acronyms:

µg/L – micrograms per liter
 ac – acute
 BHC – benzene hexachloride
 ch – chronic
 COC – constituent of concern
 fw – freshwater
 NAS – Naval Air Station
 NOAA – National Oceanic Atmospheric Administration
 ORNL – Oak Ridge National Laboratory
 SVOC – semivolatile organic compound
 sw – saltwater
 VOC – volatile organic compound
 -- No value reported

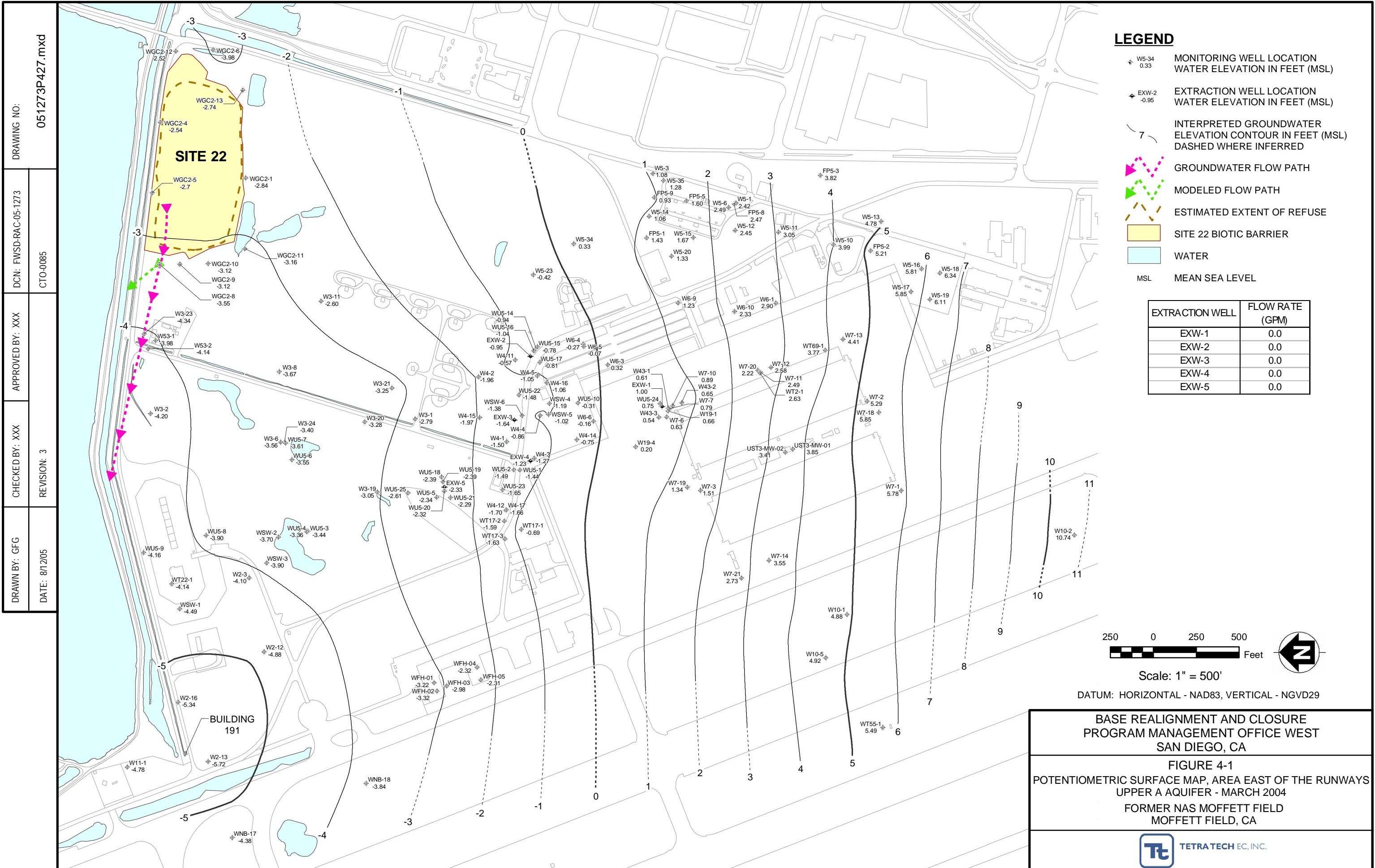


TABLE 4-4
**CALCULATED CONCENTRATION LIMITS FOR CONSTITUENTS OF CONCERN, SITE 22
FORMER NAS MOFFETT FIELD**

COC^(a)	Saltwater Value^(b) (µg/L)	Concentration Ratio	Attenuation Factor	RL (µg/L)	Calculated Concentration Limit^(c) (µg/L)
VOCs					
Benzene	700	2.57E+01	25.70	1	17,990
Chlorobenzene	129	7.80E+04	100	1	12,900
Chloroform	2.8	4.87E+00	4.87	1	13.64
cis-1,2-Dichloroethene ^(d)	59	3.03E+00	3.03	1	178.77
Ethylbenzene	43	3.95E+07	100	1	4,300
Toluene	5,000	2.56E+17	100	1	500,000
Trichloroethene	4.7	2.45E+01	24.50	1	115.15
Vinyl chloride ^(d)	59	2.58E+00	2.58	1	152.22
Xylene (total) ^(e)	0.18	9.93E+05	100	3	18
Pesticides					
Aldrin	0.13	infinite	100	0.05	13
gamma-BHC (Lindane)	0.016	infinite	100	0.05	1.6
SVOCs					
1,4-Dichlorobenzene	129	6.42E+07	100	10	12,900
2-Methylnaphthalene	30	infinite	100	10	3,000
4-Methylphenol ^(f)	1.3	3.50E+10	100	10	130
bis(2-Ethylhexyl)phthalate	0.3	infinite	100	20	30
Carbazole ^(g)	0.37	infinite	100	10	37
Dibenzofuran	0.37	infinite	100	10	37
Diethylphthalate	3.4	1.24E+10	100	20	340
Fluorene	30	infinite	100	10	3,000
Naphthalene	235	1.88E+19	100	10	23,500

Notes:

- (a) Analytes that did not appear in any of the four criteria sources were assigned surrogates. Surrogates were chosen based on the criteria described in Section 4.1.1.
- (b) Saltwater chronic values were derived by applying a safety factor of 10 if the most appropriate criteria available were saltwater acute or freshwater chronic values.
- (c) Calculated concentration limit was the chronic saltwater value multiplied by the attenuation factor.
- (d) 1,2-Dichloroethene was used as a surrogate.
- (e) m-Xylene was used as a surrogate.
- (f) 2-Methylphenol was used as a surrogate. 3/4-Methylphenol report by analytical laboratory.
- (g) Dibenzofuran was used as a surrogate.

Abbreviations and Acronyms:

- µg/L – micrograms per liter
 BHC – benzene hexachloride
 COC – constituent of concern
 NAS – Naval Air Station
 OMMP – Operations, Maintenance, and Monitoring Plan
 RL – laboratory reporting limit
 SVOC – semivolatile organic compound
 TtFW - Tetra Tech FW, Inc.
 VOC – volatile organic compound

limited number of observations used to characterize a natural system. The Navy accounted for uncertainties by selecting the most conservative site- and chemical-specific input parameters for the model.

4.1.3 Derivation of CCLs for Groundwater

The surface water screening values (AWQC, if available; saltwater chronic value or equivalent) were multiplied by the respective AF to derive CCLs for groundwater for each COC. The CCLs are presented in Table 4-4.

4.1.3.1 CCL Development Uncertainties

Uncertainties regarding the development of the CCLs include the conservative assumptions used to select the screening criteria and those used to calculate AFs. For some analytes, appropriate screening criteria exist. Surface water screening levels that are derived using SFs or surrogate chemicals may be overly conservative.

The AFs used to develop the CCLs also contribute to the conservative approach and uncertainty of the CCL. Standard methods were used during the development of the AFs, including an EPA-accepted model and site-specific input parameters, where possible. In some cases, highly conservative values were used in the model (such as hydraulic conductivity). The Navy accounted for uncertainties by selecting the most conservative site- and chemical-specific input parameters for the model.

4.2 MONITORING POINTS

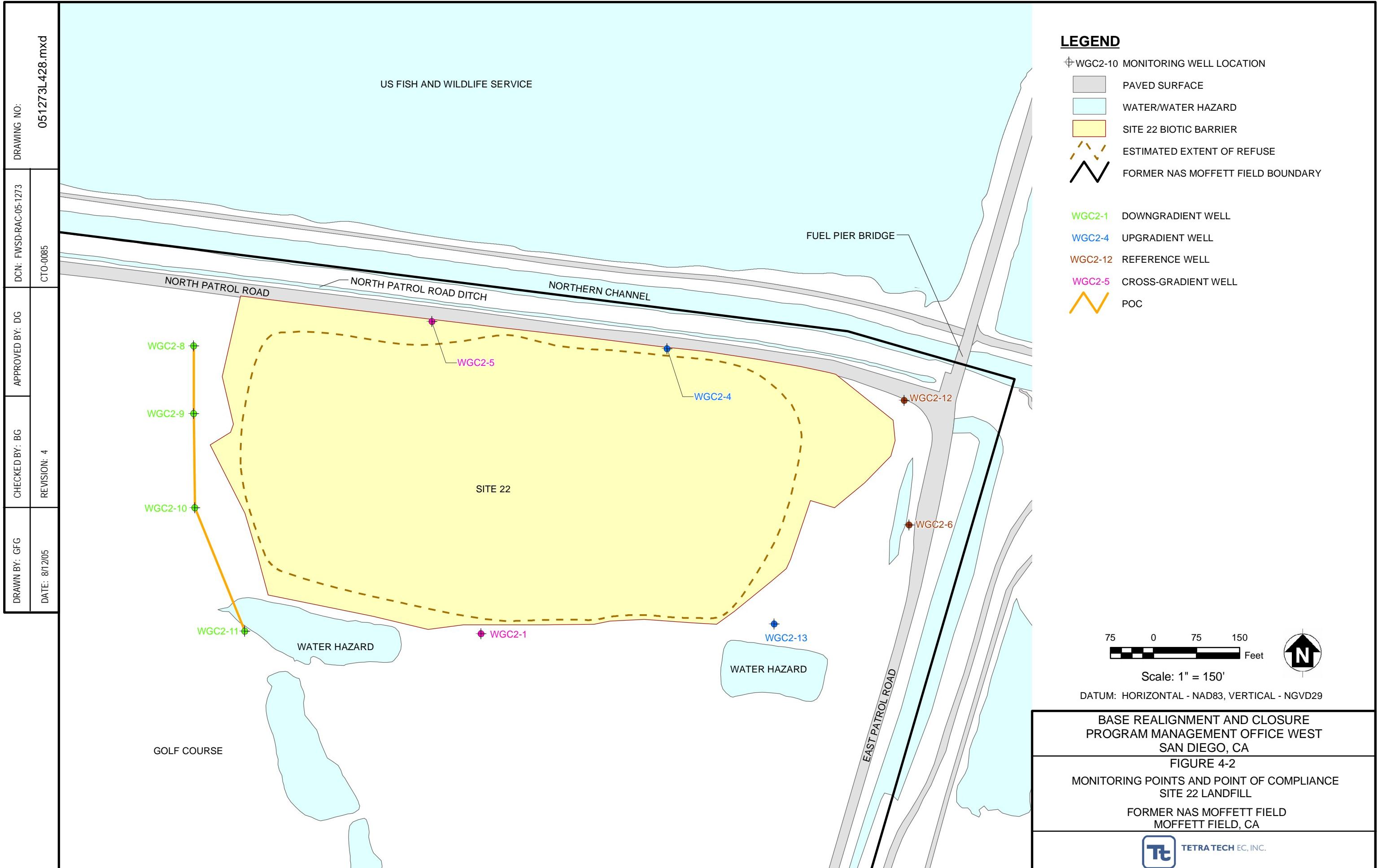
The Site 22 Landfill monitoring network consists of 10 groundwater monitoring wells (Figure 4-2). All of the groundwater monitoring wells are screened in the upper portion of the A aquifer. The monitoring network, including the identification of upgradient and downgradient wells, was first discussed in the OMMP (TtFW, 2003). The groundwater monitoring network was re-evaluated after baseline monitoring was conducted. As a result, changes have been made to the proposed groundwater monitoring network. The baseline data show that there is a groundwater divide to the east of the refuse. Therefore, some of the monitoring wells originally identified as background (upgradient) wells have been reclassified as reference wells. A reference well is similar to an upgradient well in that it provides hydrologic data about groundwater at the site, but does not contain groundwater that will flow under the landfill. The monitoring points for Site 22 and the rationale for each location are described below:

- **WGC2-8** – This monitoring well is located in the northwest corner of the site. The monitoring well is considered a downgradient well and is located along the POC.

- **WGC2-9** – This monitoring well is located in the west side of the site and south of well WGC2-8. The monitoring well is considered a downgradient well and is located along the POC.
- **WGC2-10** – This monitoring well is located in the west side of the site and south of well WGC2-9. The monitoring well is considered a downgradient well and is located along the POC.
- **WGC2-11** – This monitoring well is located in the southwest corner of the site south of well WGC2-10 by the edge of a water hazard. The monitoring well is considered a downgradient well and is located along the POC.
- **WGC2-4** – This monitoring well is located along North Patrol Road toward the east end of the site, just north of the green for hole 7. This monitoring well is considered upgradient and not impacted by groundwater flowing beneath the site.
- **WGC2-13** – This monitoring well is located on the southwest edge of the green for hole 2. This monitoring well is considered upgradient and not impacted by groundwater flowing beneath the site.
- **WGC2-6** – This monitoring well is located along East Patrol Road on the east end of the site. This monitoring well is considered a reference well and is useful for determining groundwater conditions relative to the site, but does not contain groundwater that will flow under the landfill.
- **WGC2-12** – This monitoring well is located along East Patrol Road on the northeast corner of the site. This monitoring well is considered a reference well and is useful for determining groundwater conditions relative to the site but does not contain groundwater that will flow under the landfill.

Two of the monitoring points sampled during the baseline monitoring period are not proposed for routine sampling. These wells include:

- **WGC2-5** – This monitoring well is located along North Patrol Road toward the middle of the site. This monitoring well is considered cross-gradient and may receive groundwater from off site. The groundwater from this monitoring well does not impact groundwater under the landfill nor does the landfill impact groundwater within this monitoring well. This monitoring well will not be monitored for water quality.
- **WGC2-1** – This monitoring well is located along the south side of the site, toward the middle of the site, between monitoring wells WGC2-11 and WGC2-13. This monitoring well is considered cross-gradient and may receive groundwater from off site. The groundwater from this monitoring well does not impact groundwater under the landfill nor does the landfill impact groundwater within this monitoring well. This monitoring well will not be monitored for water quality.



4.3 POINT OF COMPLIANCE

The POC for Site 22 was chosen based on the groundwater flow conditions, in accordance with the ROD and applicable regulations. The locations presented in this Operations, Maintenance, and Monitoring Plan (OMMP) Addendum differ slightly from that presented in the OMMP based on the results for the baseline monitoring activities, and agreement from the EPA and Regional Water Quality Control Board (RWQCB). Groundwater elevations and flow direction have been consistent during the baseline evaluation period, showing a consistent flow toward the west. Therefore, the POC for Site 22 is the hydraulic downgradient boundary of Site 22 between monitoring wells WGC2-8 and WGC2-11 (see Figure 4-2).

4.4 DATA EVALUATION PROCESS

This section describes the data evaluation process and illustrates how the statistical methods (described in Appendix E) will be applied to the groundwater chemical data for the Site 22 detection monitoring program. Figure 4-3 shows the groundwater evaluation process according to the ROD and Title 27 for the Site 22 Landfill.

Title 27 California Code of Regulations (CCR), §20420, describes the elements of a groundwater detection monitoring program, including the data evaluation process. According to 27 CCR, §20420(i), data collected during detection monitoring are compared to background data to determine if there is evidence of a release from the landfill based on a measurably significant (MS) change in groundwater monitoring data. According to 27 CCR, §20164, MS means “a change in the monitoring point data that, relative to the reference background value (or other approved reference value or distribution), is sufficient to indicate that a release has occurred, pursuant to the applicable data analysis method (including its corresponding trigger).” Therefore, if data are found to be MS, then that is an indication of a release from the unit. If a release is indicated, then the discharger will notify the RWQCB immediately, and the discharger has the option of data verification [Title 27 CCR, §20420(j)(2)].

The proposed Site 22 groundwater detection monitoring program follows the intent of the 27 CCR and complies with the overriding elements of the ROD. The proposed Site 22 landfill groundwater detection monitoring program involves comparing the validated analytical results on an analyte-by-analyte basis to the respective CCL to determine whether there has been an exceedance. The ROD specifies that the Navy initially evaluates the groundwater chemical data by comparing downgradient monitoring point concentrations directly to the CCLs (Navy, 2002). If all analytical results are less than or equal to the respective CCL, no further action is necessary. If one or more analytes are greater than the respective CCL, a data review of background concentrations and statistical methods (detailed in Appendix E) will be applied to evaluate those specific analyte(s). Analytes detected at estimated concentrations (at a concentration between the method detection level [MDL] and the sample quantitation level

[SQL]) will be considered detections. This approach is consistent with the statistical approach used to evaluate the data.

For each analyte that exceeds the CCL in a particular monitoring well, statistical methods will be used to determine if there is a statistically significant difference between the pooled background (upgradient and reference wells) population⁶ and the pooled downgradient population⁷. The statistical analysis compares the pooled population, which includes current and all historical data, with the latest sampling results. Each sampling event will add new data, so the population changes through time. The background (upgradient and reference) well data are pooled for this analysis because the null hypothesis⁸ treats the upgradient and reference well data as a single data population for comparison to an individual downgradient monitoring well. From a statistical perspective, all of the individual upgradient and reference wells represent conditions outside the influence of the landfill. Any changes reflected in the upgradient and reference wells are expected to be derived from outside influences and, thus, could affect a downgradient well.

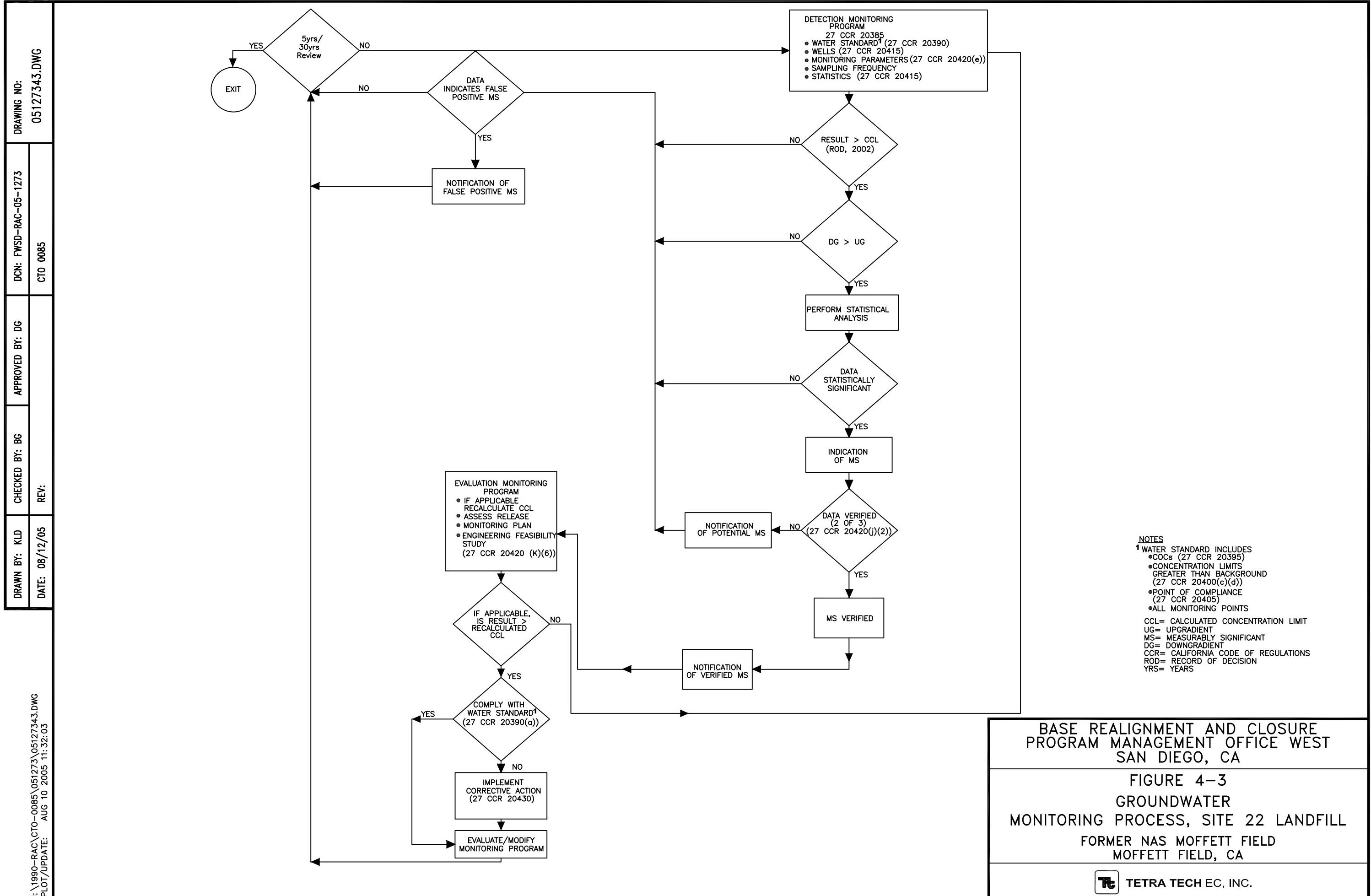
The null hypothesis assumes that there is no difference between the downgradient and background (upgradient and reference) populations. That is, any differences in analyte concentrations within the data sets are minor and tend to vary around a similar central point (see Appendix E, Section 2.3). If the background and downgradient populations either vary widely around the central point, or consist of different central points for each population, the test would indicate a statistically significant difference between the populations. While the statistical methods can indicate these differences, the underlying source of the statistical significance is not specified. For example, upgradient concentrations may have more variation around the central point and, thus, cause the statistical difference. But which particular monitoring well or particular data point within the population may have caused the significant difference cannot be determined.

If there is a statistically significant difference (between the pooled background population and the pooled downgradient population), the data will be further evaluated to determine if the statistically significant difference may be due to the analyte concentration (for the current sampling event) in the downgradient well being either lower or higher than the concentrations (current and historical) of the same analyte in the individual background and reference wells. If the current data point at the particular downgradient well is lower than any data point in the background (upgradient and reference) wells, then the statistically significant difference would be attributed to an increase in a background or reference well concentration and not due to a

⁶ The pooled upgradient (background) population is the current and historical concentrations for the analyte for the background monitoring wells (WGC2-4 and WGC2-13) and reference wells (WGC2-6 and WGC2-12).

⁷ The pooled downgradient population is the current and historical concentrations for the analyte for the individual downgradient monitoring well.

⁸ The null hypothesis describes what is assumed to be the true state of nature, while the alternative hypothesis describes the opposite situation.



release from the Site 22 Landfill. Therefore, no further action will be required. However, if the analyte concentrations (current and historical) in all of the background (upgradient and reference) wells are lower than the current downgradient data point concentration, then a release has likely occurred from the landfill based on a MS change in the monitoring data. If there is an indication of a MS change in the monitoring data, the Navy will notify the EPA and the RWQCB of such an event. The sampling results will then be verified in accordance with Title 27 CCR, §20420 (j)(2). Samples will be collected for each verification sampling event within 30 days of receipt of the validated data from the previous sampling event [Title 27 CCR, §20415 (e)(8)(E)(3)]. Verification samples will be analyzed only for those analytes that exceeded the CCL in the initial sampling event that indicated a potential release from the landfill.

Verification of a result occurs when all of the following conditions are proved in any two out of three consecutive groundwater sampling events:

- An analyte exceeds its respective CCL.
- Pooled data in a particular downgradient well are compared to pooled background (upgradient and reference) well data, and there is a statistically significant difference.
- The statistically significant difference is due to the current sampling event analyte concentration in the downgradient well(s) being greater than the pooled background and reference well(s) concentrations.

A deviation in any of the three conditions described above means the data are not verified (the initial condition was a false positive result), and there is no MS change in the monitoring data. Defining verification by using two out of three consecutive groundwater sampling events is intended to respond to proven trends and eliminate false positives, where a chemical concentration causes statistical significance in one round and then reverts to being not statistically significant in subsequent sampling events. This practice is consistent with California monitoring guidance (Department of Toxic Substance Control, 2001). If the data are verified and there is a MS change in monitoring data, the Navy will notify the EPA and the RWQCB, and an evaluation-monitoring program will be initiated⁹ after agency acceptance. If a MS change in the data is not verified, the EPA and the RWQCB will be notified that the previous indication of a MS change in the monitoring data was a false positive, and a release from the Site 22 Landfill has not occurred.

⁹ If the concentration of an analyte triggering a MS change in monitoring data exceeds a CCL, and if this CCL was developed with a screening value that is based on the use of SFs or surrogate chemicals, then the aquatic toxicity of the analyte will be reviewed in more detail, and the CCL will be recalculated with more chemical-specific data.

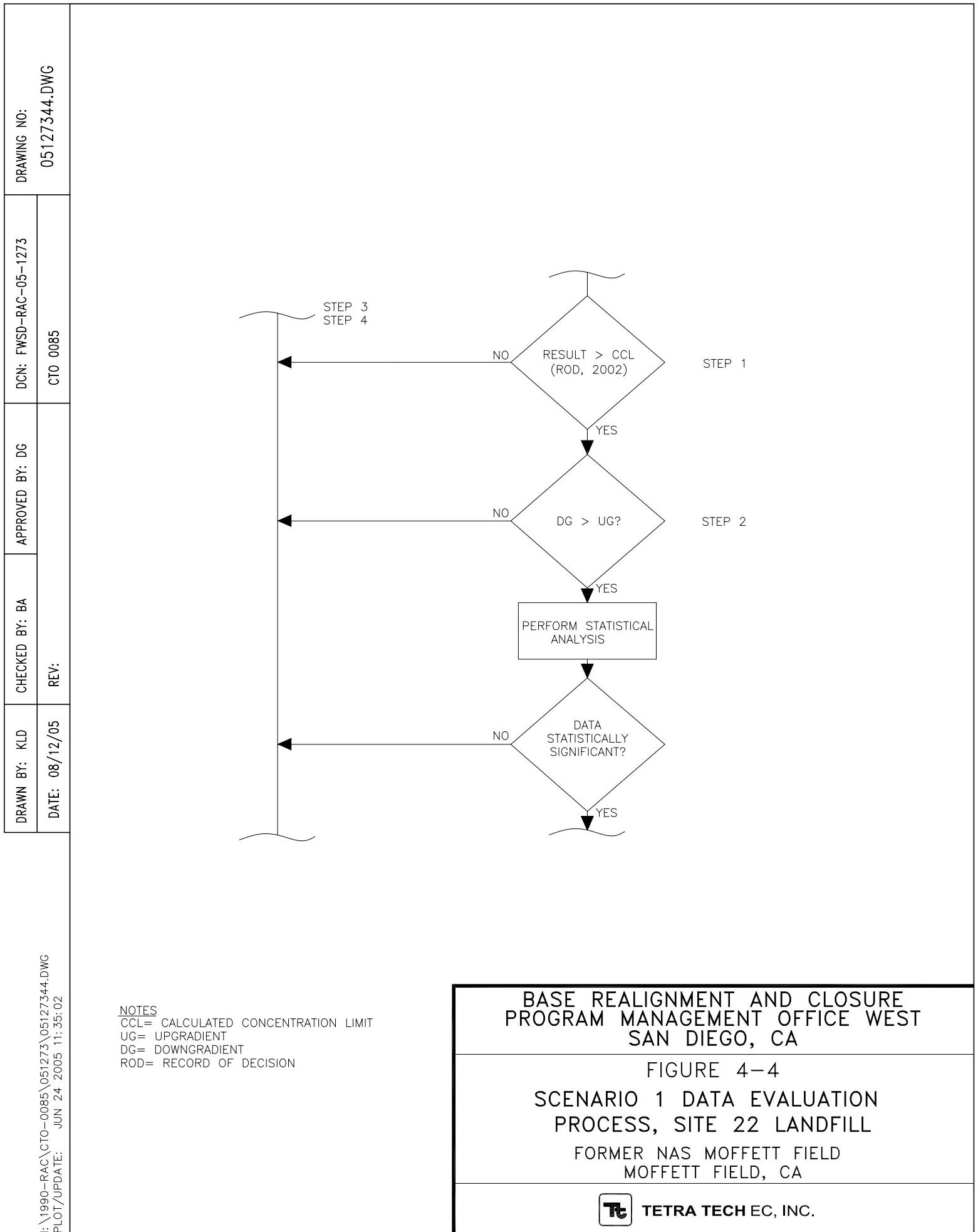
Three hypothetical scenarios are described below to better explain the Site 22 groundwater detection monitoring program data evaluation process described above. The scenarios describe the specific steps taken during the data evaluation process.

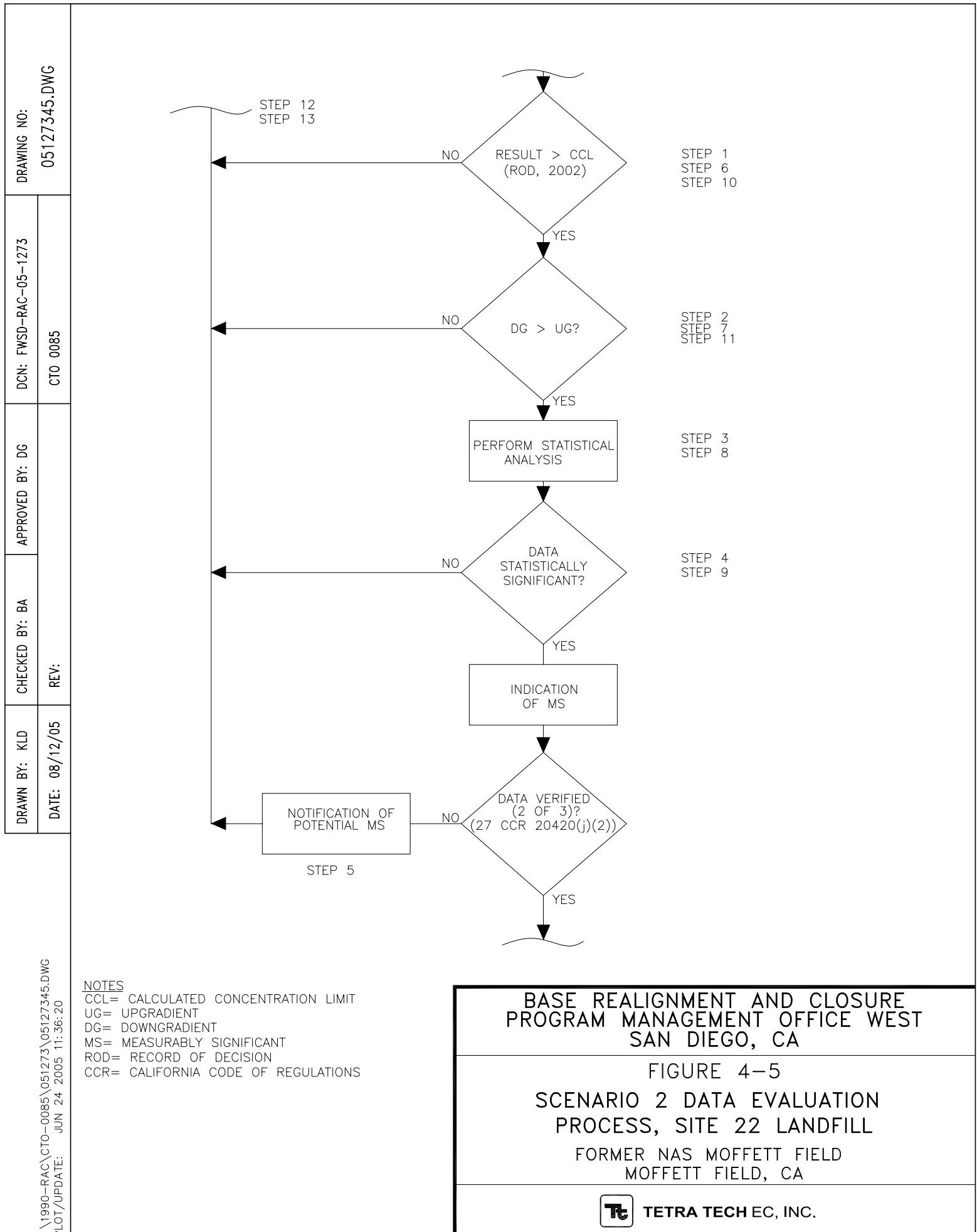
Scenario 1 (Figure 4-4): Downgradient Less Than Background

1. Concentration of analyte A is above the CCL for analyte A.
2. The current sampling event concentration of analyte A in the downgradient well is lower than the current or historical concentrations for analyte A in one or more of the background (upgradient and reference) wells.
3. There is no release from within the landfill.
4. No further action is required.

Scenario 2 (Figure 4-5): MS Change Not Confirmed 2 out of 3

1. Concentration of analyte B is above the CCL for analyte B.
2. The current sampling event concentration of analyte B in the downgradient monitoring well is greater than the current or historical concentrations for analyte B in all of the background (upgradient and reference) wells.
3. Statistics are performed for analyte B (per Appendix E).
4. Pooled analytical results for analyte B in the downgradient well are statistically significant relative to the pooled background (upgradient and reference well) for analyte B.
5. The data indicate a MS change in monitoring data. However, the result must be verified in any one of the next two sampling events. The Navy will notify the EPA and the RWQCB.
6. For the verification sampling event, the concentration of analyte B is again above the CCL for analyte B.
7. The verification sampling event concentration of analyte B in the downgradient monitoring well is greater than the current or historical concentrations for analyte B in all of the background (upgradient and reference) wells.
8. Statistics are again performed for analyte B (per Appendix E).
9. Pooled analytical results for analyte B in the downgradient well are not statistically significant relative to the pooled background (upgradient and reference wells) for analyte B.
10. For the second verification sampling event, the concentration of analyte B is again above the CCL for analyte B.
11. The current sampling event concentration of analyte B in the downgradient well is lower than the current or historical concentrations for analyte B in one or more of the background (upgradient and reference) wells.





12. There is no release from within the unit. The differences in the two pooled populations are not statistically significant for two out of three sampling events. There is no measurably significant change in the monitoring data.
13. The Navy will notify the EPA and the RWQCB that the previous indication that the data were measurably significant was a false positive, and a release from the Site 22 Landfill has not occurred.
14. No further action is required.

Scenario 3 (Figure 4-6): MS Change Confirmed

1. Concentration of analyte C is above the CCL for analyte C.
2. The current sampling event concentration of analyte C in the downgradient monitoring well is greater than the current or historical concentrations for analyte C in all of the background (upgradient and reference) wells.
3. Statistics are performed for analyte C (per Appendix E).
4. Pooled analytical results for analyte C in the downgradient monitoring well are statistically significant relative to the pooled background (upgradient and reference wells) for analyte C.
5. The data indicate a measurably significant change in monitoring data. However, the results must be verified in any one of the next two sampling events. The Navy will notify the EPA and the RWQCB.
6. For the first verification sampling event, the concentration of analyte C is again above the CCL for analyte C.
7. The first verification sampling event concentration of analyte C in the downgradient well is greater than the current or historical concentrations for analyte C in all of the background (upgradient and reference) wells.
8. Statistics are again performed for analyte C (per Appendix E).
9. Pooled analytical results for analyte C in the downgradient monitoring well are statistically significant relative to the pooled background (upgradient and reference wells) for analyte C.
10. The data indicate a measurably significant change in monitoring data in two sampling events. The Navy will notify the EPA and the RWQCB.
11. An evaluation monitoring program will be initiated.

The groundwater evaluation monitoring program, as specified in Title 27 CCR, §20425 will be used to assess the nature and extent of the release from the unit and to design a corrective action program meeting the requirements of Title 27 CCR, §20430, if necessary. The steps for the evaluation monitoring program are as follows:

- Re-evaluate Specific CCL Exceedance – Aquatic toxicity of the analyte will be reviewed in more detail, and the concentration limit may be recalculated with more chemical-specific data and/or site-specific data. If there is still an exceedance, then the following actions will be taken:
 - Delineate Release – Collect and analyze all data necessary to assess the nature and extent of the release from the landfill
 - Engineering Feasibility Study – Develop an Engineering Feasibility Study for corrective action
 - Corrective Action Program – Establish a Corrective Action Program to implement selected remedies
 - Monitoring Plan – Develop a monitoring program that demonstrates the effectiveness of the Corrective Action Program

4.5 MONITORING PARAMETERS

MPs include physical and analytical parameters that are subsets of the COCs. The physical parameters proposed are typical water quality parameters used during groundwater sampling. The physical MPs for the Site 22 Landfill are temperature, conductivity, dissolved oxygen, salinity, pH, and turbidity.

The analytical MPs were selected based on the criteria presented in Title 27, including frequency of detections, analyte mobility, analyte persistence, potential degradation products, class similarities, toxicity to aquatic receptors, and reported operational history of the landfill. Table 4-5 provides an overview of the analytical MP selection process.

VOCs were added to the MP list based on the potential that they may occur at the site due to the reported material present. The VOCs selected are shown below, along with the rationale for their selection:

- **Chloroform** – Chloroform was detected consistently in downgradient monitoring well WGC2-9 during the baseline monitoring period from November 2003 through October 2004 (Section 3.2.1 and Appendix B, Table B-1). Chloroform is highly soluble in water at 9,300 milligrams per liter (mg/L) at 25 degrees centigrade (Montgomery and Welkom, 1990). It has a low K_{oc} (minimum reported value) of 39.8 milliliters per gram (mL/g), and a long half-life (maximum reported value) of 43,200 hours (Appendix D, Table D.4-1). Therefore, it is considered to be mobile and persistent in the aquifer. It is considered toxic to aquatic receptors [chronic saltwater screening value of 2.8 micrograms per liter ($\mu\text{g}/\text{L}$), see Table 4-4]. Chloroform was selected as an MP based on its detections, mobility, persistence in the aquifer, class similarities, and toxicity to aquatic receptors.
- **Cis-1,2-Dichloroethene (cis-1,2-DCE)** – Cis-1,2-DCE was detected in downgradient monitoring well WGC2-8 at trace concentrations in five of the eight events during the baseline monitoring period from November 2003 through October 2004 (Section 3.2.1

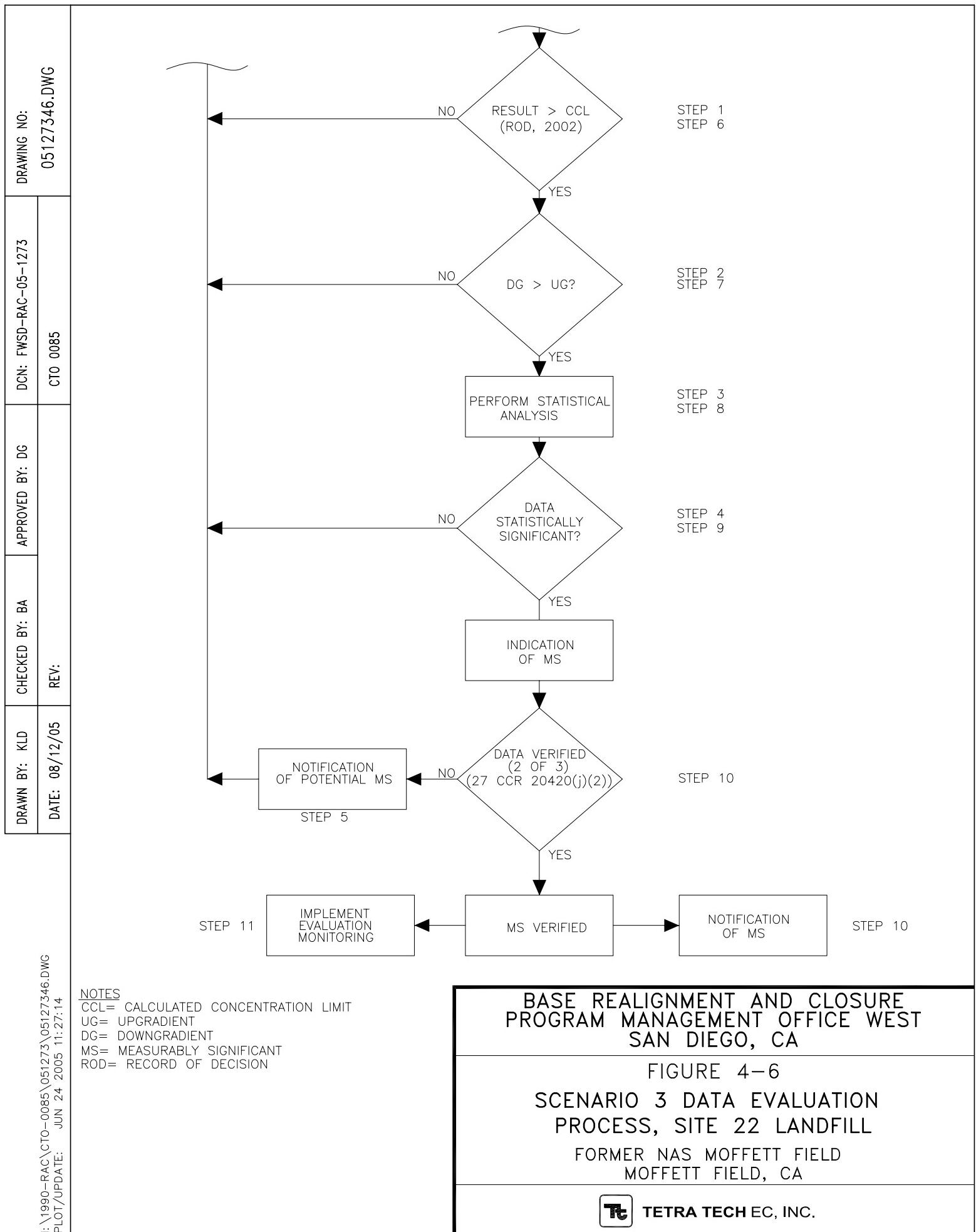


TABLE 4-5

**PROPOSED MONITORING PARAMETERS AND SELECTION RATIONALE,
SITE 22, FORMER NAS MOFFETT FIELD**

	Selection Basis	Number of Detections	Solubility (mg/L)	K_{oc}^(a) (mL/g)	Half-life (hours)
VOCs					
Chloroform	1, 2, 3, 5, 6	13	9,300 ^(a)	39.8	1,344 – 43,200
cis-1,2-Dichloroethene	1, 2, 3, 4, 5	5	6,300 ^(a,b)	35.5	1,344 – 69,000
Trichloroethene	1, 2, 3, 5, 6, 7	16	1,100 ^(a)	166	7,704 – 39,672
Xylene	3, 5, 6	1	175 ^(a)	363	336 – 8,640

Selections are based on a combination of the following:

1. Detections
2. Mobility (K_{oc})
3. Persistence (half-life)
4. Degradation product
5. Class similarities
6. Toxicity to aquatic receptors
7. Reported operational history

Notes:

^(a) At 25 degrees centigrade (Montgomery and Welkom, 1990)

^(b) Value shown is for the isomer trans-1,2-dichloroethene

Abbreviations and Acronyms:

K_{oc} – soil-water partitioning coefficient

mg/L – milligrams per liter

mL/g – milliliters per gram

NAS – Naval Air Station

VOC – volatile organic compound

and Appendix B, Table B-1). It is highly soluble in water at 6,300 mg/L at 25 degrees centigrade (Montgomery and Welkom, 1990). It has a low K_{oc} (minimum reported value) of 35.5 mL/g, and a long half-life (maximum reported value) of 69,000 hours (Appendix D, Table D.4-1). Therefore, it is considered to be mobile and persistent in the aquifer. Cis-1,2-DCE is a degradation product of trichloroethene (TCE), and it is more stable under anaerobic conditions (which is the environment expected under a landfill). It is a good indicator of the potential presence of chlorinated organics. It is considered toxic to aquatic receptors (chronic saltwater screening value of 59 μ g/L (see Table 4-4)). Cis-1,2-DCE was selected as an MP based on its detections, mobility, persistence in the aquifer, potential as a degradation product of TCE, class similarities, and toxicity to aquatic receptors.

- **TCE** – TCE was detected consistently in downgradient monitoring wells WGC2-9 and WGC2-8 (Section 3.2.1 and Appendix B, Table B-1). It has moderate solubility in water of 1,100 mg/L at 25 degrees centigrade (Montgomery and Welkom, 1990). TCE has a relatively low K_{oc} (minimum reported value) of 166 mL/g and a long half-life (maximum reported value) of 39,672 hours (Appendix D, Table D.4-1). Therefore, it is considered to be mobile and persistent in the aquifer. TCE is denser than lighter fraction VOCs and is a good indicator of the potential presence of chlorinated solvents. It is considered highly toxic to aquatic receptors (chronic saltwater screening value of 4.7 μ g/L; see Table 4-4). TCE was selected as an MP based on its detections, mobility, persistence in the aquifer, class similarities, toxicity to aquatic receptors, and the reported operational history of the Site 22 Landfill.
- **Xylene (Total)** – Xylene has been detected once at the site in September 1994 at an estimated concentration of 2J μ g/L in a sample from cross-gradient monitoring well WGC2-5. The o-xylene isomer has a moderately low solubility in water of 175 mg/L at 25 degrees centigrade (Montgomery and Welkom, 1990). O-Xylene has a moderate K_{oc} of 363 mL/g (EPA, 1996). It has a relatively moderate half-life in groundwater (maximum reported value) of 8,640 hours (McKay et al., 1992a; 1992b; 1993; 1995a; 1995b). All three xylene isomers have moderate to high aquatic toxicity, with a chronic freshwater screening value of 1.8 μ g/L. Xylene was selected as an MP based on its persistence, moderate to high toxicity, and the reported operational history of the Site 22 Landfill.
- The VOCs selected as MPs were based on the frequency of detection and/or properties of each compound, with those selected that would be most likely to be present in the groundwater. The rationale for VOCs not selected as MPs is as follows:
 - **Benzene** – Benzene was detected twice in September 1994 and once in June of 1995, all three times at estimated concentrations. It is moderately soluble in water at 1,800 mg/L at 25 degrees centigrade (Montgomery and Welkom, 1990). Benzene has a moderate K_{oc} of 58.9 mL/g (EPA, 1996), and thus, is less mobile than those selected as MPs. It has a relatively long half-life in groundwater (maximum reported value) of 17,280 hours (McKay et al., 1992a; 1992b; 1993; 1995a; 1995b). Benzene has a high aquatic toxicity, with a chronic saltwater screening value of 700 μ g/L. Accordingly, it is considerably less toxic than the VOCs selected as MPs. Therefore, based on the limited number of detection, and low toxicity to aquatic receptors, benzene was not selected as a MP.

- **Chlorobenzene** – Chlorobenzene has never been detected in a sample from a Site 22 Landfill groundwater monitoring well. It has low solubility in water (maximum reported value) of 502 mg/L at 25 degrees centigrade (Montgomery and Welkom, 1990). Chlorobenzene has a moderate K_{oc} of 219 mL/g (EPA, 1996), and thus, is less mobile than those selected as MPs. It has a moderate half-life in groundwater (maximum reported value) of 7,200 hours (McKay et al., 1992a; 1992b; 1993; 1995a; 1995b). Chlorobenzene has a moderate chronic screening value of 129 $\mu\text{g}/\text{L}$. Therefore, due to the lack of detections, low mobility, and moderate toxicity to aquatic receptors, chlorobenzene was not selected as a MP.
- **Ethylbenzene** – Ethylbenzene has never been detected in a sample from a Site 22 Landfill groundwater monitoring well. It has a low solubility in water (maximum reported value) of 208 mg/L at 25 degrees centigrade (Montgomery and Welkom, 1990). Ethylbenzene has a moderate K_{oc} of 363 mL/g (EPA, 1996), and thus is less mobile than the selected MPs. It has a moderate half-life in groundwater, (maximum reported value) of 5,472 hours (McKay et al., 1992a; 1992b; 1993; 1995a; 1995b). Ethylbenzene has a moderate aquatic toxicity, with an acute saltwater screening value of 430 $\mu\text{g}/\text{L}$. Based on the lack of detections, low mobility, and moderate toxicity to aquatic receptors, ethylbenzene was not selected as a MP.
- **Toluene** – Toluene has been detected once since June 1995 at an estimated concentration of 0.22J $\mu\text{g}/\text{L}$ in a sample collected from upgradient monitoring well WGC2-13 (November 2003). It has a moderate solubility in water (maximum reported value) of 524 mg/L at 25 degrees centigrade (Montgomery and Welkom, 1990). Toluene has a moderately low K_{oc} of 182 mL/g (EPA, 1996). It has a relatively short half-life in groundwater (maximum reported value) of 672 hours (McKay et al., 1992a; 1992b; 1993; 1995a; 1995b), which indicates that it is less persistent than any of the VOCs selected as MPs. Toluene has a low aquatic toxicity, with a saltwater screening value of 5,000 $\mu\text{g}/\text{L}$. Accordingly, it is considerably less toxic than the VOCs selected as MPs. Therefore, due to the limited number of detections and low toxicity to aquatic receptors, toluene was not selected as a MP.
- **Vinyl Chloride** – Vinyl chloride has never been detected in a sample from a Site 22 Landfill groundwater monitoring well. It is highly soluble in water at 2,700 mg/L at 25 degrees centigrade (Montgomery and Welkom, 1990). Vinyl chloride has a low K_{oc} of 18.6 mL/g (EPA, 1996). It has a relatively long half-life in groundwater, (maximum reported value) of 69,000 hours (McKay et al., 1992a; 1992b; 1993; 1995a; 1995b), which indicates that it is more persistent. Vinyl chloride has a moderately low aquatic toxicity, with a chronic freshwater screening value of 590 $\mu\text{g}/\text{L}$. Accordingly, it is less toxic than the VOCs selected as MPs. Based on the lack of detections and low toxicity to aquatic receptors, vinyl chloride was not selected as a MP.

There were no semivolatile organic compounds (SVOCs) added to the MP list. The rationale for SVOCs not selected as MPs is as follows:

- **Bis(2-Ethylhexyl)phthalate (BeP)** – BeP has been detected once at the site since April 1998 at an estimated concentration of 11J $\mu\text{g}/\text{L}$ in a sample from reference well WGC2-

6. BeP is a common laboratory contaminant. It has low solubility in water of 0.34 mg/L at 25 degrees centigrade (Montgomery and Welkom, 1990). BeP has a very high K_{oc} of 15,100,000 mL/g (EPA, 1996), and thus, binds strongly to soils. It has a moderate half-life in groundwater (maximum reported value) of 9,336 hours (McKay et al., 1992a; 1992b; 1993; 1995a; 1995b). BeP is relatively toxic to aquatic receptors, with a saltwater screening value of 0.3 μ g/L. Due to its moderate persistence and low toxicity, BeP was selected as a MP.

- **1,4-Dichlorobenzene (1,4-DCB)** – 1,4-DCB has never been detected in a Site 22 Landfill groundwater monitoring well. It has low solubility in water at 79 mg/L at 25 degrees centigrade (Montgomery and Welkom, 1990). It has a relatively long half-life in groundwater (maximum reported value) of 8,640 hours (McKay et al., 1992a; 1992b; 1993; 1995a; 1995b), which indicates that it is more persistent. It has a moderate K_{oc} of 617 mL/g (EPA, 1996) and a moderate aquatic toxicity, with a chronic saltwater screening value of 129 μ g/L. Based on the lack of detections, 1,4-DCB was not selected as a MP.
- **2-Methylnaphthalene** – 2-Methylnaphthalene has never been detected in a Site 22 Landfill groundwater monitoring well. It has low solubility in water at 24.6 mg/L at 25 degrees centigrade (Montgomery and Welkom, 1990). 2-Methylnaphthalene has a high K_{oc} (maximum reported value) of 8,511 mL/g (EPA, 1996) and tends to bind to soil; thus, it is relatively immobile. It has a relatively long half-life in groundwater (maximum reported value) of 10,000 hours (McKay et al., 1992a; 1992b; 1993; 1995a; 1995b), which indicates that it is more persistent. 2-Methylnaphthalene has a moderate to low aquatic toxicity, with an acute saltwater screening value of 300 μ g/L. Based on the lack of detections, poor mobility, and moderate to low toxicity, 2-methnaphthalene was not selected as a MP.
- **4-Methylphenol** – 4-Methylphenol has never been detected in a Site 22 Landfill groundwater monitoring well. Information regarding its solubility is not available; however, 2-methylphenol (used as a surrogate for 4-methylphenol) is highly soluble in water at 25,000 mg/L at 25 degrees centigrade (Montgomery and Welkom, 1990). 2-Methylphenol has a moderate K_{oc} of 91.2 mL/g (EPA, 1996). It has a relatively short half-life in groundwater of 876 hours (McKay et al., 1992a; 1992b; 1993; 1995a; 1995b), which indicates that it is not persistent. 2-Methylphenol has a moderate aquatic toxicity, with a chronic freshwater screening value of 13 μ g/L. Based on the lack of detections and limited persistence, 4-methylphenol was not selected as a MP.
- **Carbazole** – Carbazole has never been detected in a Site 22 Landfill groundwater monitoring well. It is considered insoluble in water. Carbazole has a high K_{oc} of 3,390 mL/g (EPA, 1996) and tends to bind to soil. It has a relatively long half-life in groundwater (maximum reported value) of 29,280 hours (McKay et al., 1992a; 1992b; 1993; 1995a; 1995b), which indicates that it persistent. Screening criteria was not available for carbazole, so dibenzofuran was used as a surrogate. Dibenzofuran has a moderate to high aquatic toxicity, with a chronic freshwater screening value of 3.7 μ g/L. Based on the lack of detections and poor mobility, carbazole was not selected as a MP.
- **Dibenzofuran** – Dibenzofuran has never been detected in a sample from a Site 22 Landfill groundwater monitoring well. It has low solubility in water at 10 mg/L at 25

degrees centigrade (Montgomery and Welkom, 1990). Dibenzofuran has a high K_{oc} of 7,800 mL/g (EPA, 1996) and tends to bind to soil. It has a short half-life in groundwater (maximum reported value) of 835 hours (McKay et al., 1992a; 1992b; 1993; 1995a; 1995b), which indicates that it is not persistent. Dibenzofuran has a moderate to high aquatic toxicity, with chronic freshwater screening value of 3.7 $\mu\text{g}/\text{L}$. Based on the lack of detections, poor mobility, and limited persistence, dibenzofuran was not selected as a MP.

- **Diethylphthalate** – Diethylphthalate has never been detected in a sample from a Site 22 Landfill groundwater monitoring well. It is moderately soluble in water at 896 mg/L at 25 degrees centigrade (Montgomery and Welkom, 1990). Diethylphthalate has a moderate K_{oc} of 288 mL/g (EPA, 1996). It has a relatively short half-life in groundwater (maximum reported value) of 2,688 hours (McKay et al., 1992a; 1992b; 1993; 1995a; 1995b). Diethylphthalate has a moderate to high aquatic toxicity, with a chronic saltwater screening value of 3.4 $\mu\text{g}/\text{L}$. Based on the lack of detections and persistence, diethylphthalate was not selected as a MP.
- **Fluorene** – Fluorene has never been detected in a sample from a Site 22 Landfill groundwater monitoring well. It has low solubility in water at 1.69 mg/L at 25 degrees centigrade (Montgomery and Welkom, 1990). Fluorene has a very high K_{oc} of 13,800 mL/g (EPA, 1996) and tends to bind to soil. It has a moderate half-life in groundwater (maximum reported value) of 2,880 hours (McKay et al., 1992a; 1992b; 1993; 1995a; 1995b), which indicates that it is not persistent. Fluorene has a low aquatic toxicity, with an acute saltwater screening value of 300 $\mu\text{g}/\text{L}$. Based on the lack of detections, poor mobility, limited persistence, and low toxicity, fluorene was not selected as a MP.
- **Naphthalene** – Naphthalene has never been detected in a sample from a Site 22 Landfill groundwater monitoring well. It has low solubility in water at 30 mg/L in water at 25 degrees centigrade (Montgomery and Welkom, 1990). Naphthalene has a high K_{oc} of 2,000 mL/g (EPA, 1996). It has a moderate half-life in groundwater, (maximum reported value) of 6,192 hours (McKay et al., 1992a; 1992b; 1993; 1995a; 1995b), which indicates that it is not persistent. Naphthalene has a low aquatic toxicity, with an acute saltwater screening value of 2,350 $\mu\text{g}/\text{L}$. Based on the lack of detections, poor mobility, limited persistence, and low toxicity, naphthalene was not selected as a MP.

There were no pesticides added to the MP list. The rationale for pesticides not selected as MPs is as follows:

- **Gamma-benzene hexachloride (BHC) (Lindane)** – Gamma-BHC was detected during November 2003 at an estimated concentration of 0.042J $\mu\text{g}/\text{L}$ in a sample from downgradient well WGC2-9, at a concentration of 0.2 $\mu\text{g}/\text{L}$ in a sample from downgradient well WGC2-11, and in a sample from reference well WGC2-12 at an estimated concentration of 0.022J $\mu\text{g}/\text{L}$. It has low solubility in water of 7.8 mg/L at 25 degrees centigrade (Montgomery and Welkom, 1990). Gamma-BHC has a high K_{oc} of 1,070 mL/g (EPA, 1996) and tends to bind to soil. It has a moderate half-life in groundwater (maximum reported value) of 5,765 hours (McKay et al., 1992a; 1992b; 1993; 1995a; 1995b). It is very toxic to aquatic receptors, with a saltwater screening

value of 0.016 µg/L. Detections of gamma-BHC in groundwater samples may be due to past practices of the golf course rather than as a compound from the refuse. Due to limited detections, limited mobility, and past practices of the golf course, gamma-BHC was not selected as a MP.

- **Aldrin** – Aldrin has been detected once since November 2003 at an estimated concentration of 0.036J µg/L in a sample from downgradient monitoring well WGC2-9 and once at a concentration of 0.1 µg/L in a sample from downgradient monitoring well WGC2-11. It has low solubility in water (maximum reported value) of 17 mg/L at 25 degrees centigrade (Montgomery and Welkom, 1990). Aldrin has an extremely high K_{oc} of 2,450,000 mL/g (EPA, 1996) and tends to bind strongly to soil. It has a relatively long half-life in groundwater of approximately 28,400 hours (McKay et al., 1992a; 1992b; 1993; 1995a; 1995b). Aldrin is very toxic to aquatic receptors, with a saltwater screening value of 0.13 µg/L. Detections of aldrin in groundwater samples may be due to past practices of the golf course rather than as a compound from the refuse. Due to limited detections, limited mobility, and past practices of the golf course, aldrin was not selected as a MP.

4.6 MONITORING FREQUENCY

In accordance with the OMMP (TtFW, 2003) eight rounds of baseline groundwater samples have been collected since November 2003. The OMMP recommended quarterly groundwater monitoring for the first 5 years of groundwater sampling. The Navy proposes changing the sampling frequency at Site 22 to a semiannual basis. This recommendation is based on historical trends in the Site 22 water levels and the limited detections of COCs in groundwater samples collected from Site 22 monitoring wells.

Data were tabulated from the site-wide quarterly groundwater gauging events that occurred from March 1992 through February 2003. The measured groundwater elevations for Site 22 monitoring wells WGC2-1, WGC2-4, WGC2-5, and WGC2-6 from March 1992 through February 2003 are plotted against time in Figure 4-7. The measured groundwater elevations for the baseline monitoring period are plotted against time in Figure 4-8. The later figure includes monitoring wells WGC2-8 through WGC2-13, which were installed in October 2003. Individually, these wells showed fluctuations varying from tenths of a foot to several feet. However, the potentiometric surface (water table), as represented by the groundwater elevations (Appendix A), shows very little change in overall shape, orientation, and gradient. The minor variation in the potentiometric surface suggests an overall constancy in groundwater flow direction and a coordinated response in groundwater elevations across the monitoring well network. This coordinated response, as well as what appears to be a seasonal trend, is apparent in the groundwater elevations plotted against time.

An analysis of groundwater elevations was made using the Seasonal Kendall Test on wells where a long-term history (more than three years of water level measurements) was available. Four

wells (WGC2-1, WGC2-4, WGC2-5, and WGC2-6) fit the criterion and were evaluated for the period August 1994 through November 2003. The test shows statistical significance in all of these monitoring wells, based on grouping groundwater elevation data into two seasons (June through November as one season and December through May as the other season). These monitoring wells characterize background (upgradient well WGC2-4 and reference well WGC2-6) and cross-gradient (wells WGC2-1 and WGC2-5) monitoring well conditions and are a representative selection across the site.

Groundwater monitoring data show trace-level detections of several of the COCs at the site, as presented in Section 3.1, with some oscillation is observed in wells WGC2-8 and WGC2-9. This apparent minor oscillation is correlated to the seasonal fluctuations in the potentiometric surface. The potentiometric surface controls the groundwater flow beneath the landfill and influences contact with subsurface soils and landfill materials. Chemical constituents in the native soils or in waste would then be dissolved into the groundwater in a pulsating fashion based on contact with the undulating water table.

Therefore, based on the sporadic chemical monitoring detections (with the exception of chloroform and TCE) and the seasonal nature of the semiannual variations in groundwater elevation, groundwater monitoring is proposed when the potentiometric surface is near the highest (February), where possible, and once about 6 months later in August. As stated above, this sampling frequency is consistent with Title 27 CCR. The Navy proposes changing the sampling frequency at Site 22 to a semiannual basis for MPs and every 5 years for the entire COC list.

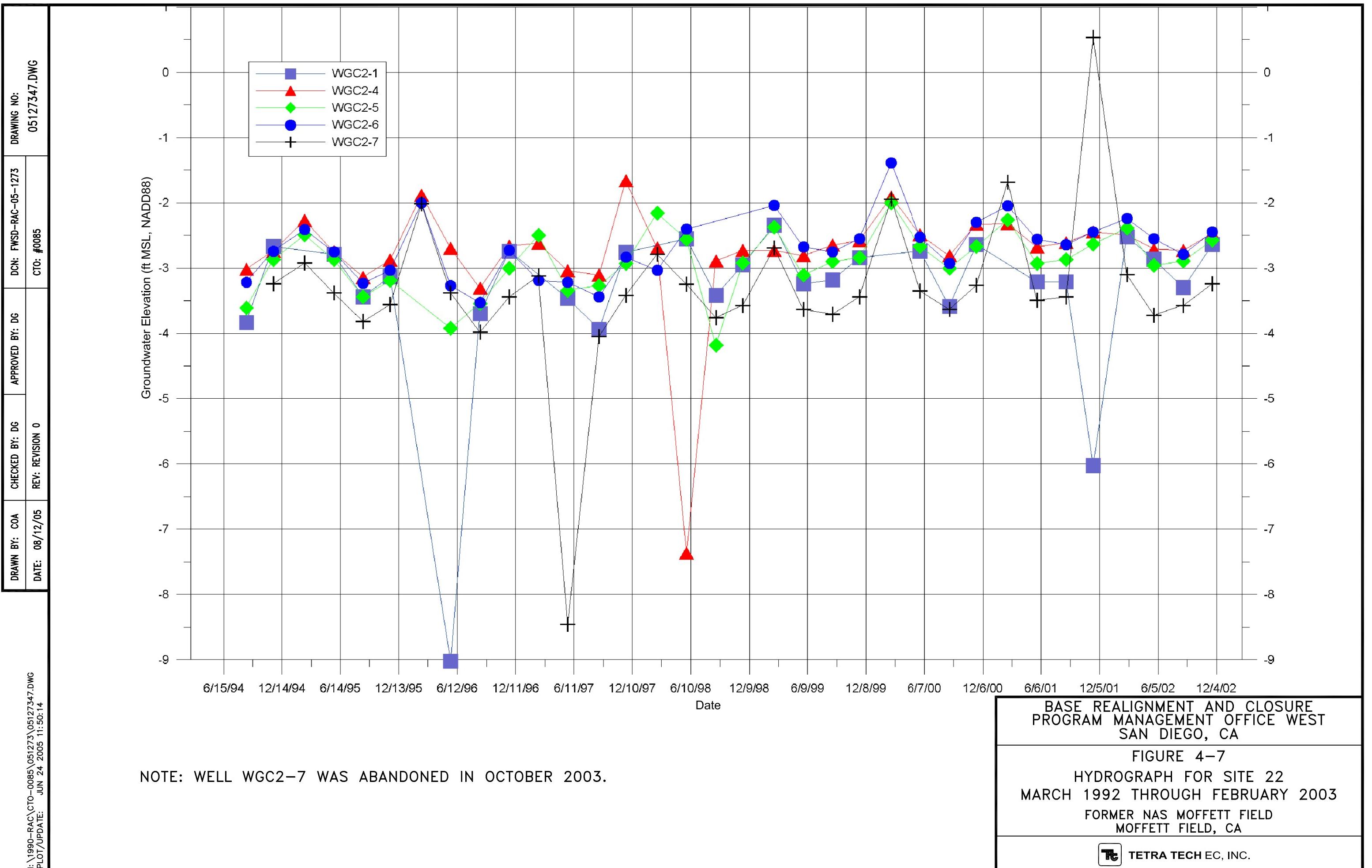
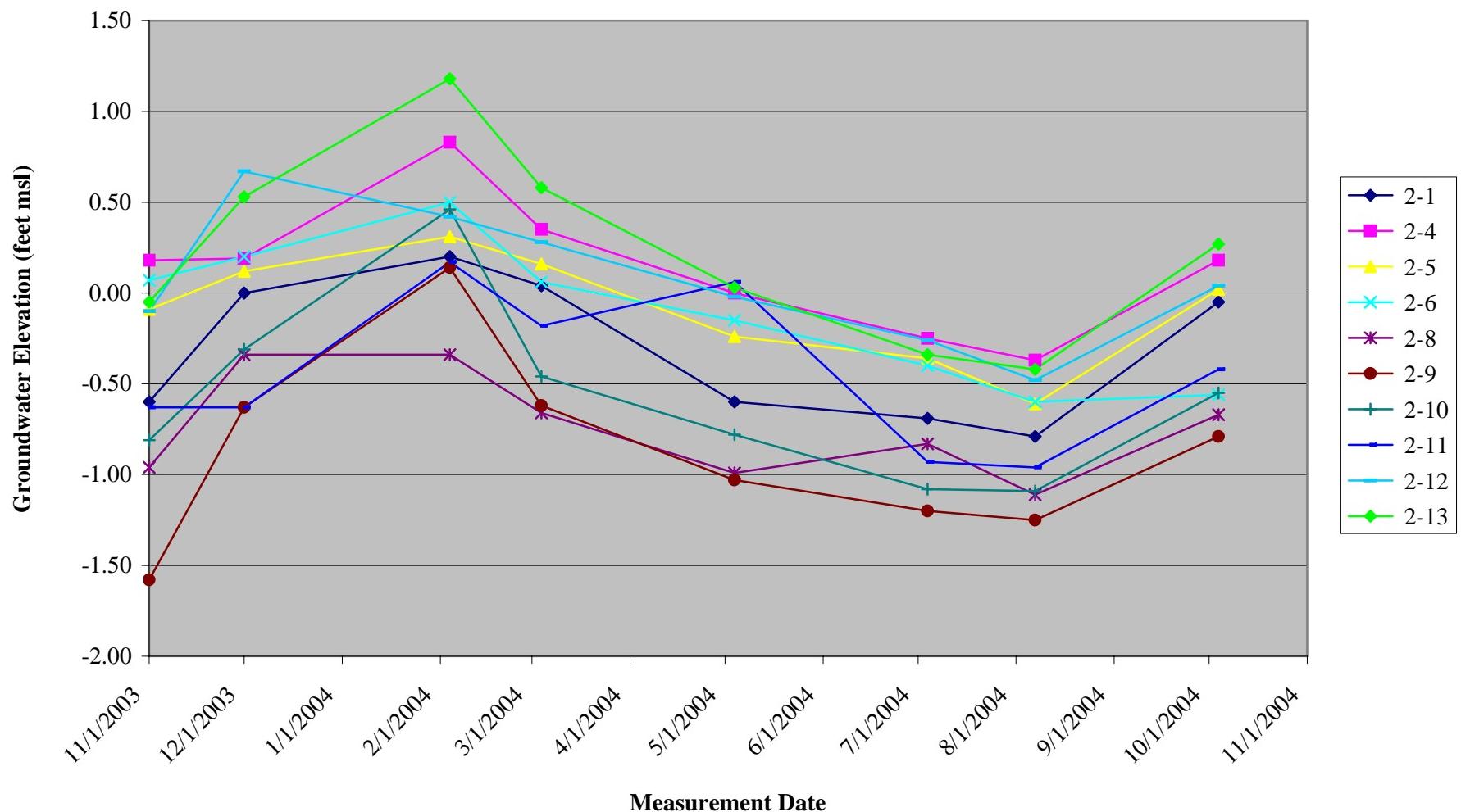


Figure 4-8

Hydrograph, Baseline Monitoring Period, Site 22 Landfill



Draft Site 22 Post-Closure
Operations, Monitoring and Maintenance Plan Addendum
Former NAS Moffett Field
DCN: FWSD-RAC-05-1273
CTO No. 0085, Revision 0, 08/12/05

5.0 METHANE DETECTION MONITORING PROGRAM

Methane monitoring will be conducted in accordance with Section 14.2 of the Record of Decision (ROD) (Department of the Navy [Navy], 2002) and Title 27 California Code of Regulations, §20921 (a), to provide for the protection of public health and safety and the environment by demonstrating that methane migration is not occurring in the vadose zone. This section describes elements of the proposed detection monitoring program, which includes landfill methane monitoring network at on-site gas monitoring wells, tree wells, and at the site boundary, and the measurement frequency.

5.1 MONITORING NETWORK

The Site 22 methane monitoring network consists of four landfill gas monitoring wells (LGMW-1, LGMW-2, LGMW-3, and LGMW-4), 15 tree wells (TW-2, -5, -9, -13, -15, -19, -21, -26, -30, -38, -40, -42, -49, -52, and -54), and 13 monitoring locations around the perimeter of the site (P-1 through P1-3) (Figure 5-1). Since there were no methane detections during the first two rounds of measurements when all 56 tree wells within the cap area were evaluated, the selected tree wells are located randomly throughout the landfill cap area. The perimeter monitoring locations are spaced about 250 feet apart along the boundary of the landfill cap.

The monitoring network was designed by a registered civil engineer and accounts for site characteristics.

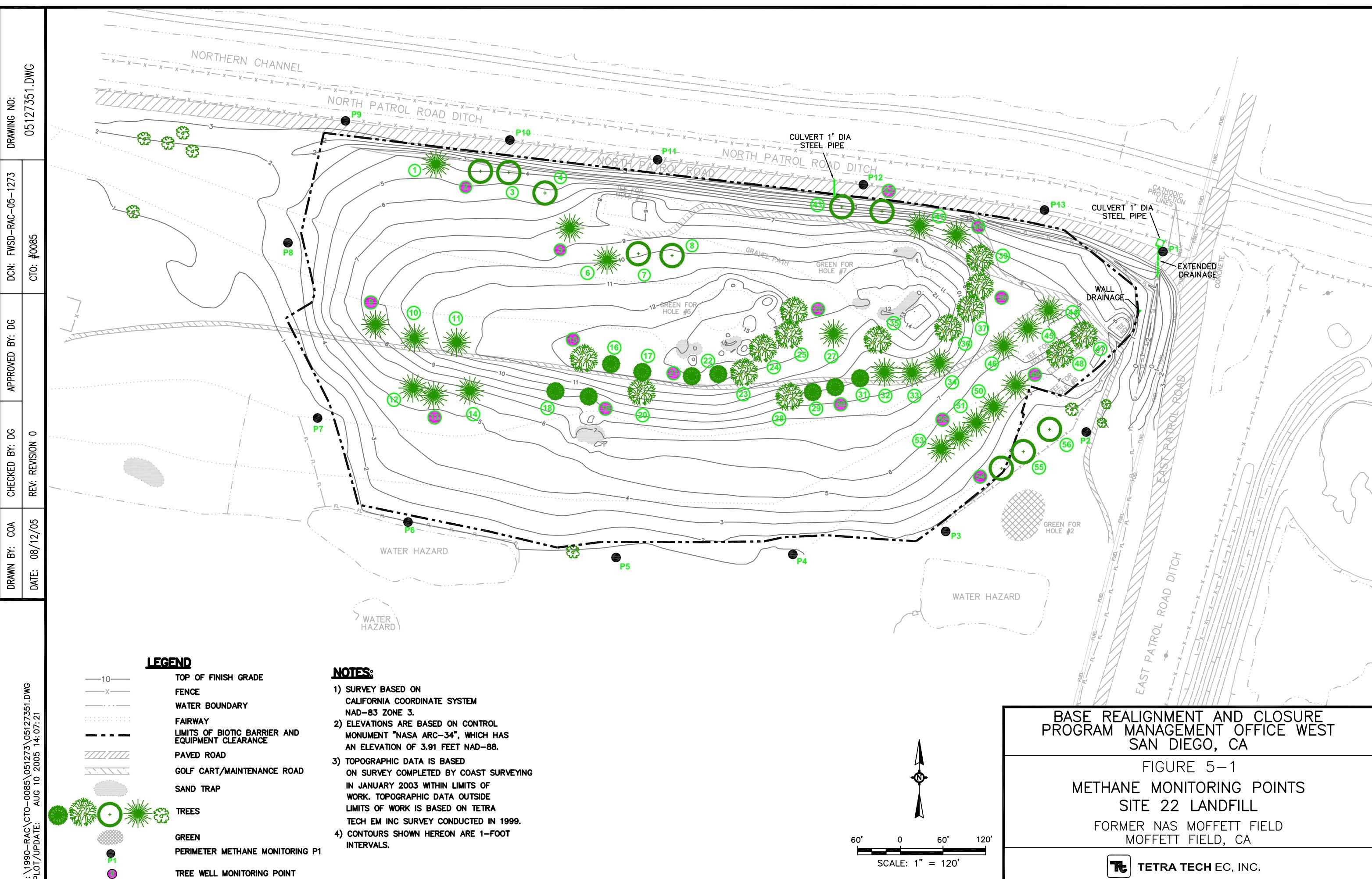
5.2 DATA EVALUATION PROCESS

Methane will be monitored to confirm that concentrations remain below 5 percent by volume in air at the site boundary. An exceedance of the criterion will be considered verified if concentrations for an individual landfill gas monitoring well, a tree well located at the boundary (TW-2, TW-42, TW-49, or TW-54), or a perimeter surface monitoring station are above this concentration for any two out of three consecutive quarters. If methane concentrations are confirmed, the U.S. Environmental Protection Agency and the Regional Water Quality Control Board, San Francisco Bay Region, will be promptly notified.

In addition, barometric pressure, atmospheric temperatures, and general weather conditions will be reported at the time of gas collection. It is recommended by the Integrated Waste Management Board to collect landfill gas during barometric low pressures. Depending on the weather, this may be late in the morning, or early in the afternoon.

5.3 MONITORING FREQUENCY

Methane monitoring will be conducted quarterly for the first 5 years, following the completion of the cap construction, and re-evaluated at that time (Section 12.2 of the ROD [Navy, 2002] and Section 3.2 of the *Appendix F Final Post-Construction, Operations, Maintenance, and Monitoring Plan* [Tetra Tech FW Inc., 2003]).



6.0 SUMMARY

This Operations, Maintenance, and Monitoring Plan (OMMP) Addendum describes the groundwater evaluation process at the Site 22 Landfill, Moffett Field, California. Groundwater data collected from the Site 22 Landfill, along with historical and regulatory guidance documents, were reviewed. Groundwater and landfill gas (methane) detection monitoring programs were developed to meet the requirements stated in the Record of Decision (ROD) (Department of the Navy [Navy], 2002) and Title 27 California Code of Regulations (CCR).

The geology beneath Site 22 consists of a complex interfingering of fine-grained units. Shallow groundwater beneath the Site 22 Landfill is found in the upper portion of the A aquifer. The primary direction of groundwater flow is to the west, influenced by pumping at Building 191, which discharges water into the Northern Channel. A component of the groundwater beneath the site may discharge to the Northern Channel. Groundwater beneath the site is neither considered a potable water source, nor is it used for municipal water supply or agricultural purposes (Navy, 2002).

The Site 22 Landfill covers approximately 9.4 acres and contains an estimated total refuse (waste) volume of 92,000 cubic yards. The site was used as an active landfill from 1950 through 1967. The refuse is believed to consist primarily of domestic waste, as confirmed through exploratory trenching. Results of environmental investigations indicate that in some places, the waste is located beneath the groundwater table, while in others, waste is located near the surface (above the groundwater table). The Site 22 Landfill now underlies holes 6 and 7 of a golf course, which is operated by the U.S. Air Force.

The ROD requires that the Navy develop a detection monitoring program which includes calculated concentration limits (CCLs) for the constituents of concern (COCs). The COCs are provided in the ROD. The groundwater beneath the Site 22 Landfill is not appropriate for beneficial use and there is no complete pathway for human exposure; therefore, there are no applicable groundwater criteria that can be used to evaluate the groundwater data. The closest point of exposure (POE) where groundwater may discharge is the Northern Channel. Various ecological screening criteria were reviewed to determine which was most technically appropriate, given the exposure pathway. Federal and state ambient water quality criteria (AWQC) screening values were selected, because at least a component of groundwater discharges to surface water, and they are protective of aquatic organisms. The federal or California chronic saltwater AWQCs were used as screening values, if available. If not available, National Oceanic and Atmospheric Administration Screening Quick Reference Table™ values were selected. If these were not available, then Oak Ridge National Laboratory values were used. Preference was given to saltwater chronic values, because the potential POE (the Northern Channel) is a brackish-water body, and chronic exposure is most protective of reproduction and

long-term health of aquatic populations. If saltwater values were not available, freshwater values were used with an appropriate safety factor (SF). To be consistent with regulatory guidance, acute values were used with an appropriate SF if chronic values were not available. For COCs that lacked screening levels, a surrogate chemical was identified, and its screening value was used.

Because concentration limits must relate surface water screening value criteria to groundwater sample results, it was necessary to develop and apply an attenuation factor (AF). An AF accounts for the natural contaminant transport processes (advection-dispersion, sorption, and degradation) that have an impact on each COC within a groundwater environment. An AF was calculated using the analytical groundwater model Analytical Transient 1-, 2-, 3-Dimensional (AT123D) by applying conservative chemical-specific and site-specific input parameters. The model was run using a simulation time of 105 years, which accounts for the 55 years since the Site 22 Landfill began operation and 50 years of future monitoring. The AT123D model predicted concentration ratios, which were used to determine the compound-specific AFs. More conservative measures were applied by truncating all resultant AF values greater than 100 to 100. The layered conservative approach (conservative input parameters and truncating AFs) accounts for uncertainty/variability in the natural hydrogeological system and geochemical fate and transport process. The compound-specific screening level was multiplied by the compound-specific AF to develop the CCL for each COC.

The monitoring points at the Site 22 Landfill include background (upgradient and reference) and downgradient monitoring wells. The wells identified as background are monitoring wells WGC2-4 and WGC2-13. The reference wells are WGC2-6 and WGC2-12. The wells identified as downgradient are monitoring wells WGC2-8, WGC2-9, WGC2-10, and WGC2-11.

The point of compliance (POC) for the Site 22 Landfill was chosen based on the groundwater flow conditions, and is defined by the ROD and applicable regulations as the hydraulic downgradient boundary of the site. Therefore, the POC at the Site 22 Landfill is along the western portion of the landfill, and it extends from monitoring well WGC2-8 on the northwest corner to monitoring well WGC2-11 on the southwest corner.

Monitoring parameters (MPs) include physical and analytical parameters that are subsets of the COCs. The physical parameters proposed are typical water quality parameters used during groundwater sampling. They include temperature, conductivity, dissolved oxygen, salinity, pH, and turbidity. MPs for routine monitoring were selected based on the criteria in Title 27 CCR, including frequency of detections, analyte mobility, analyte persistence, potential degradation products, class similarities, toxicity to aquatic receptors, and reported operational history of the Site 22 Landfill. Analytical MPs selected for the Site 22 Landfill are cis-1,2-dichloroethene, chloroform, trichloroethene, and xylene. Semivolatile organic compounds and pesticides were not selected as MPs due to their failure to meet the criteria for MPs (detections, mobility,

persistence, degradation product, class similarities, toxicity to aquatic receptors, and operational history) relative to the selected compounds.

The data evaluation process follows the requirements of the ROD and Title 27. Regularly scheduled groundwater sampling data of the MPs will be compared to the respective CCL to determine whether there is an exceedance. If downgradient analytical data are lower than or equal to the respective CCLs, then no further action will be necessary. If a downgradient analyte is greater than the respective CCL, then a statistical evaluation will be required. If there is a statistically significant difference between the pooled background (upgradient and reference) well population for the specific analyte in all of the background (upgradient and reference) monitoring wells versus the pooled downgradient population for the analyte at a particular monitoring well, the data will be further evaluated to determine if the statistically significant difference is due to the analyte concentration (for the current sampling event) in the downgradient well being lower/greater than the concentrations (current and historical) of the same analyte in the individual background and/or reference wells. If the current data point at the particular downgradient well is lower than any one data point in the upgradient/reference wells, then the statistically significant difference is attributed to an increase in a background and/or reference well concentration and is not due to a release from the Site 22 Landfill. No further action will be required. However, if the analyte concentrations in all of the upgradient/reference wells are lower than the current downgradient data point concentrations, then a release has likely occurred from the landfill based on a measurably significant change in the monitoring data. If there is an indication of a measurably significant change in the monitoring data, the Navy will notify the U.S. Environmental Protection Agency and the Regional Water Quality Control Board of such an event. The sampling results will then be verified in two out of three consecutive sampling events in accordance with Title 27 CCR, §2040 (j)(2). Samples will be collected for each verification sampling event within 30 days of receipt of the validated data from the previous sampling event [Title 27 CCR, §20415 (e)(8)(E)(3)]. Verification samples will be analyzed only for those analytes that exceeded the CCL in the initial sampling event that indicated a potential release from the landfill.

The Navy proposes semiannual monitoring at Site 22 for MP, and every 5 years for the entire COC list. This recommendation is based on well-defined historical trends in the Site 22 water levels (groundwater flow direction) and the sporadic detections of COCs in the groundwater. Groundwater sampling is proposed when the potentiometric surface is generally the highest (February) and about 6 months later when the potentiometric surface is lowest (August).

The groundwater evaluation process described in this proposed plan is in accordance with the ROD. The evaluation process provides a systematic methodology to evaluate analytical results from groundwater monitoring events to comply with the ROD and Title 27, and to protect the environment.

Methane monitoring will be conducted in accordance with Section 14.2 of the ROD and Title 27 CCR, §20921 (a), to provide for the protection of public health and safety and the environment by demonstrating that methane migration is not occurring in the vadose zone. The Site 22 methane monitoring network consists of four landfill gas monitoring wells, 15 tree wells, and 13 monitoring locations around the perimeter of the site. Methane will be monitored to confirm that concentrations remain below 5 percent by volume in air at the site boundary.

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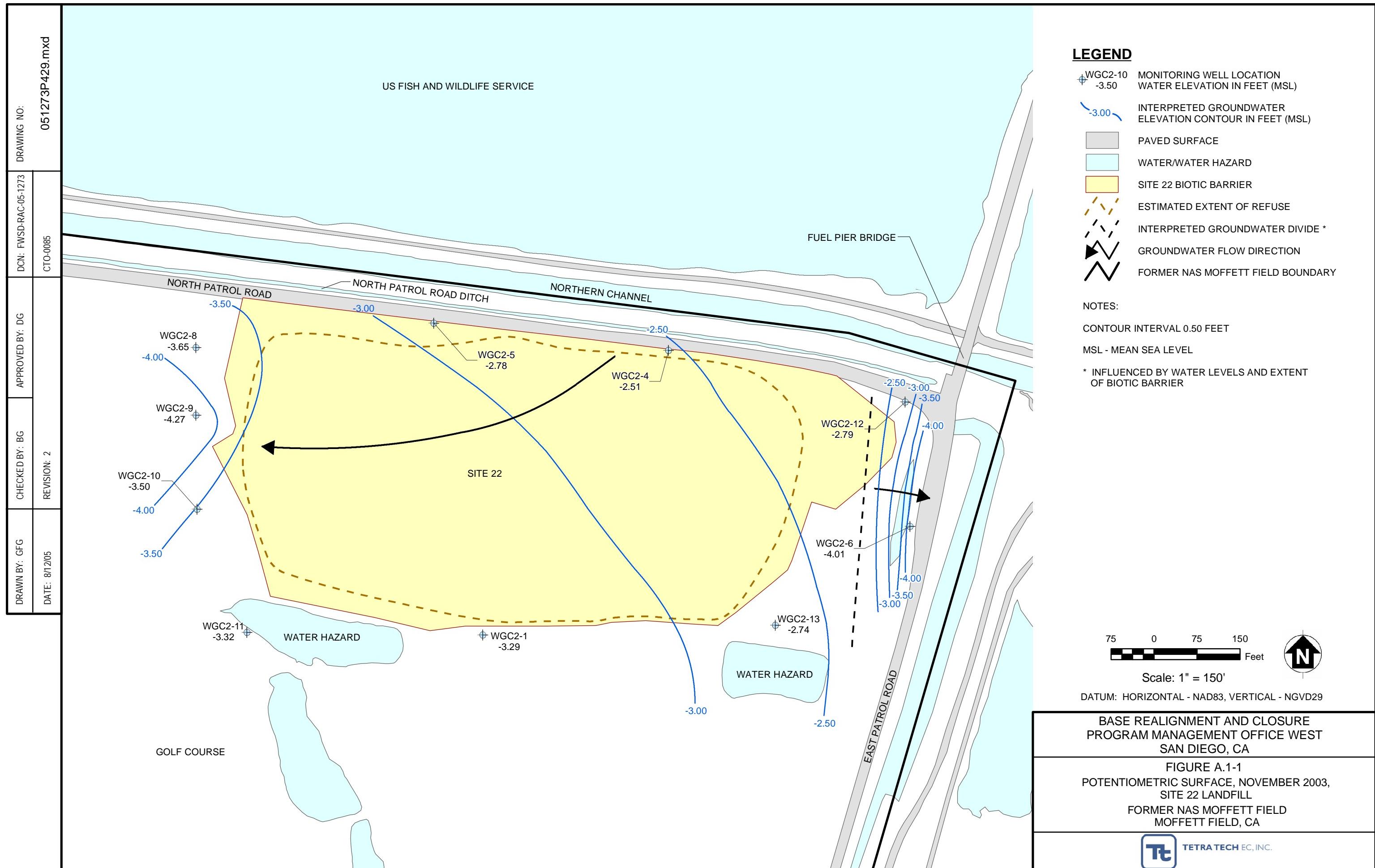
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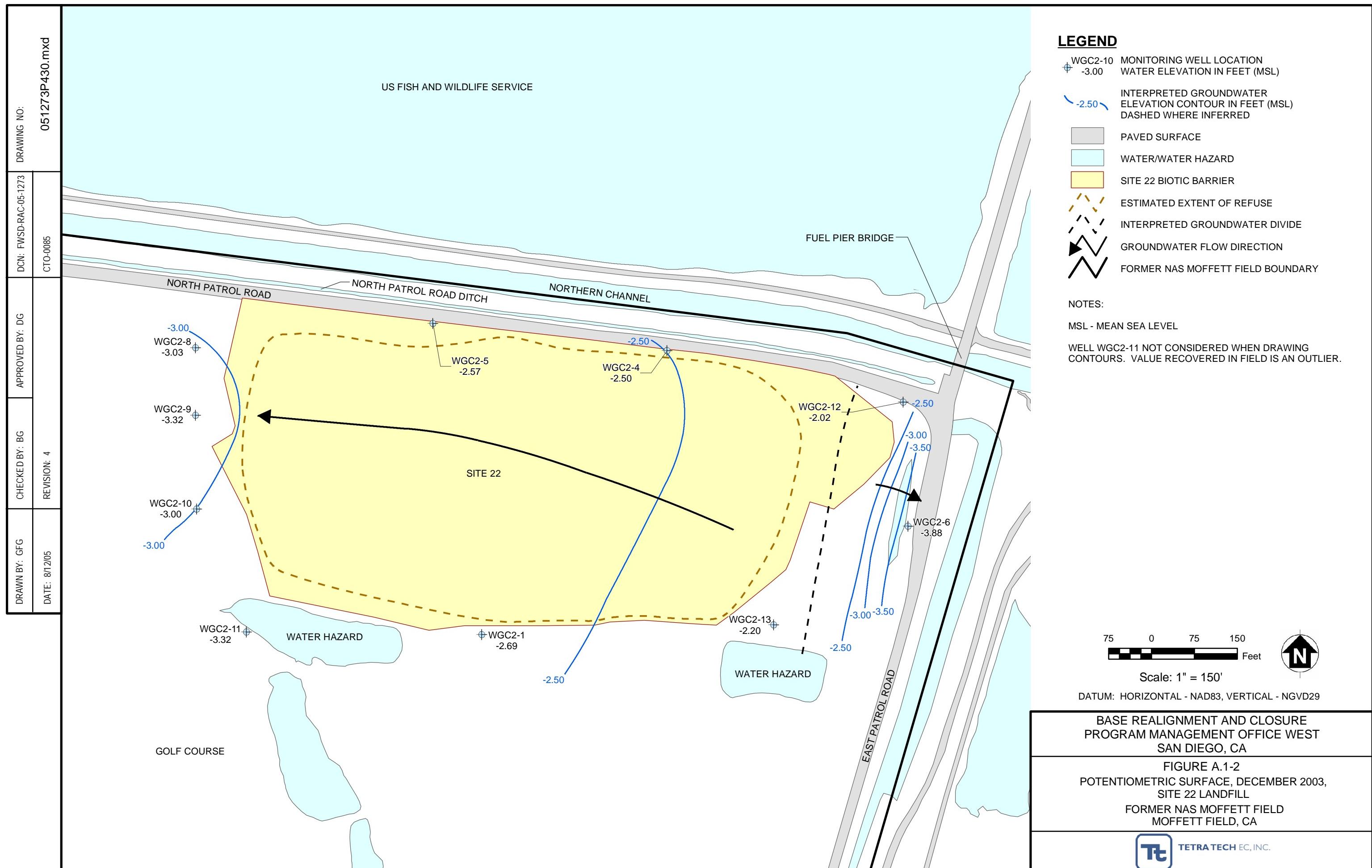
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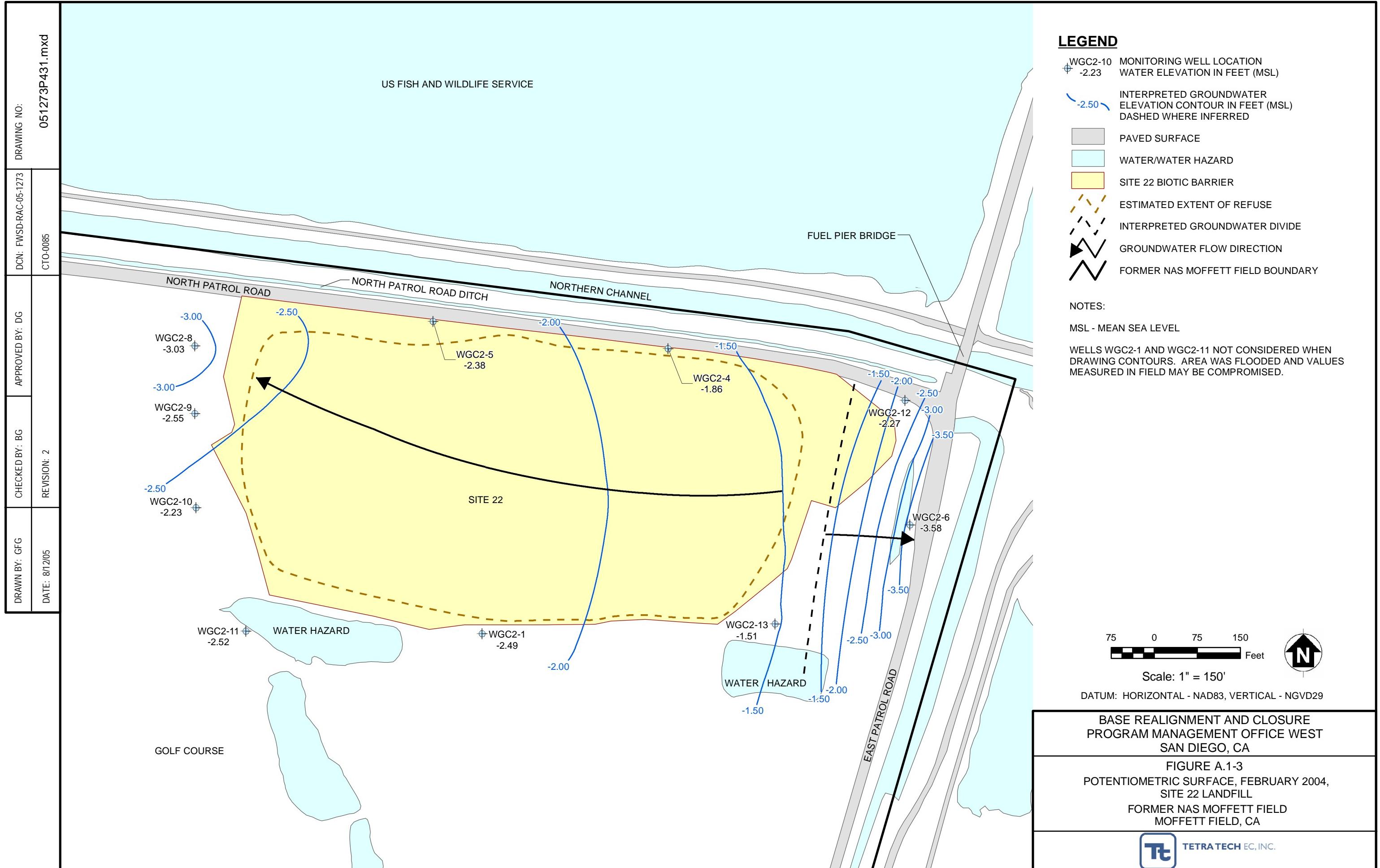
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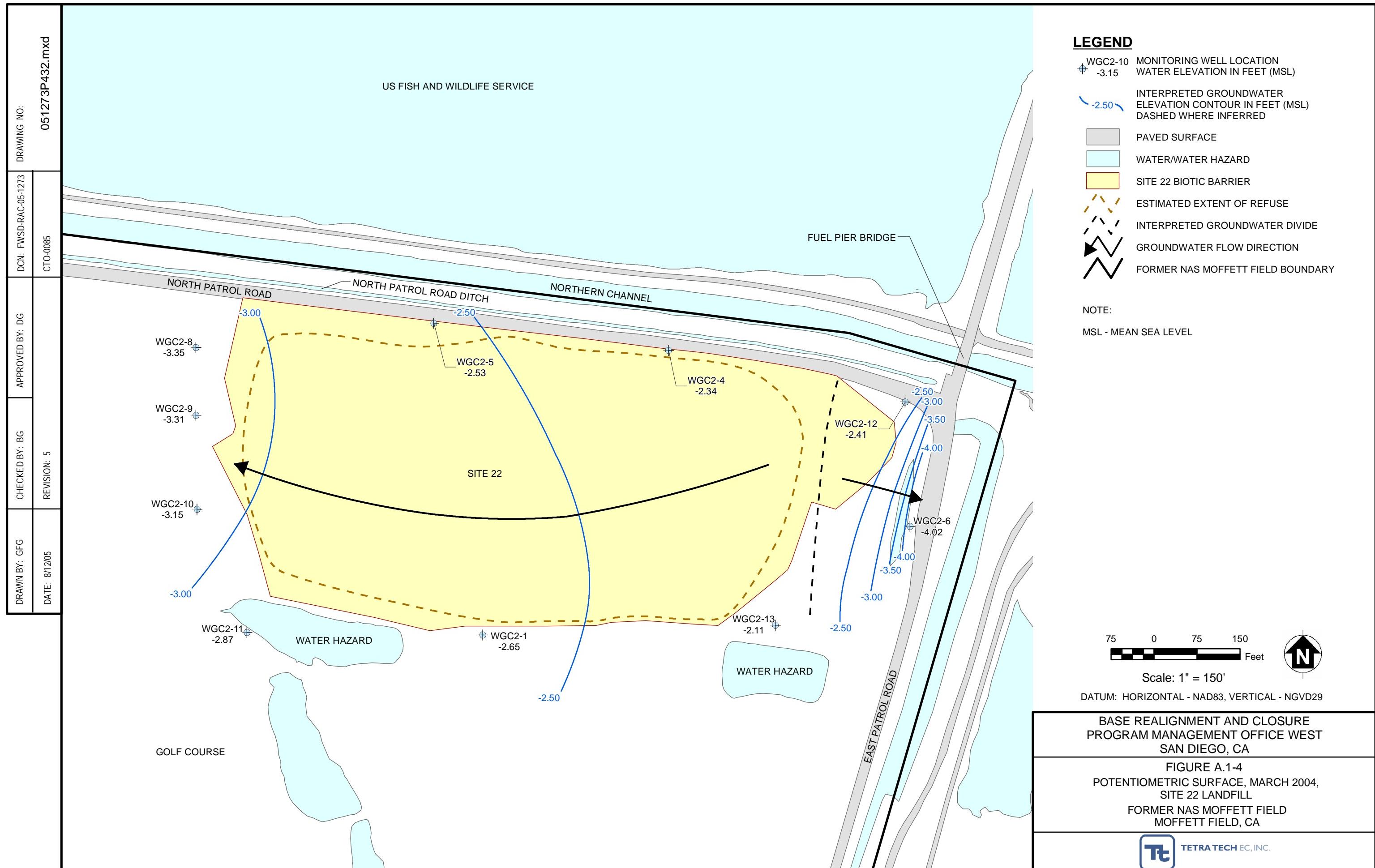
APPENDIX A

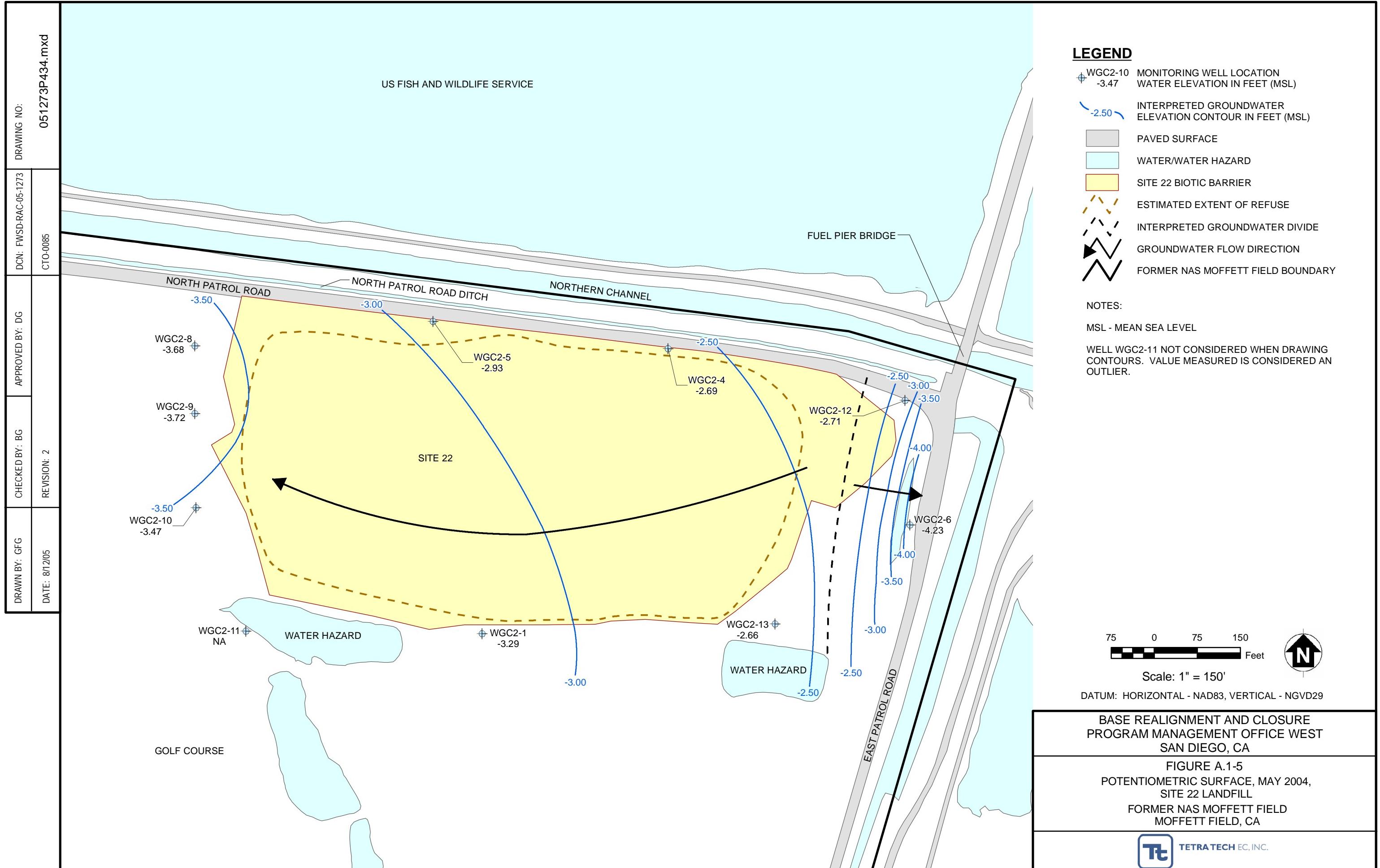
POTENTIOMETRIC SURFACE MAPS FOR SITE 22
NOVEMBER 2003 THROUGH OCTOBER 2004

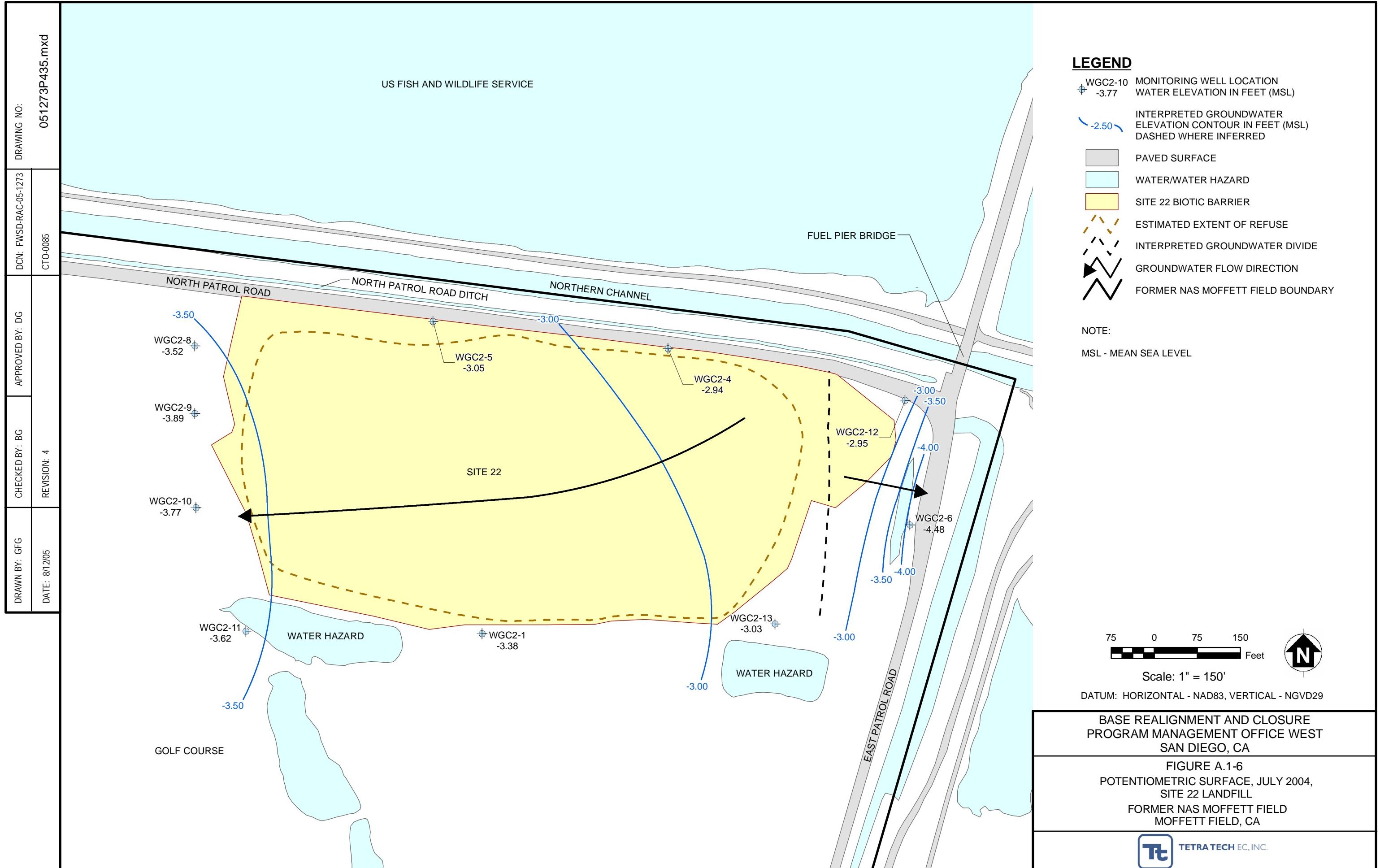


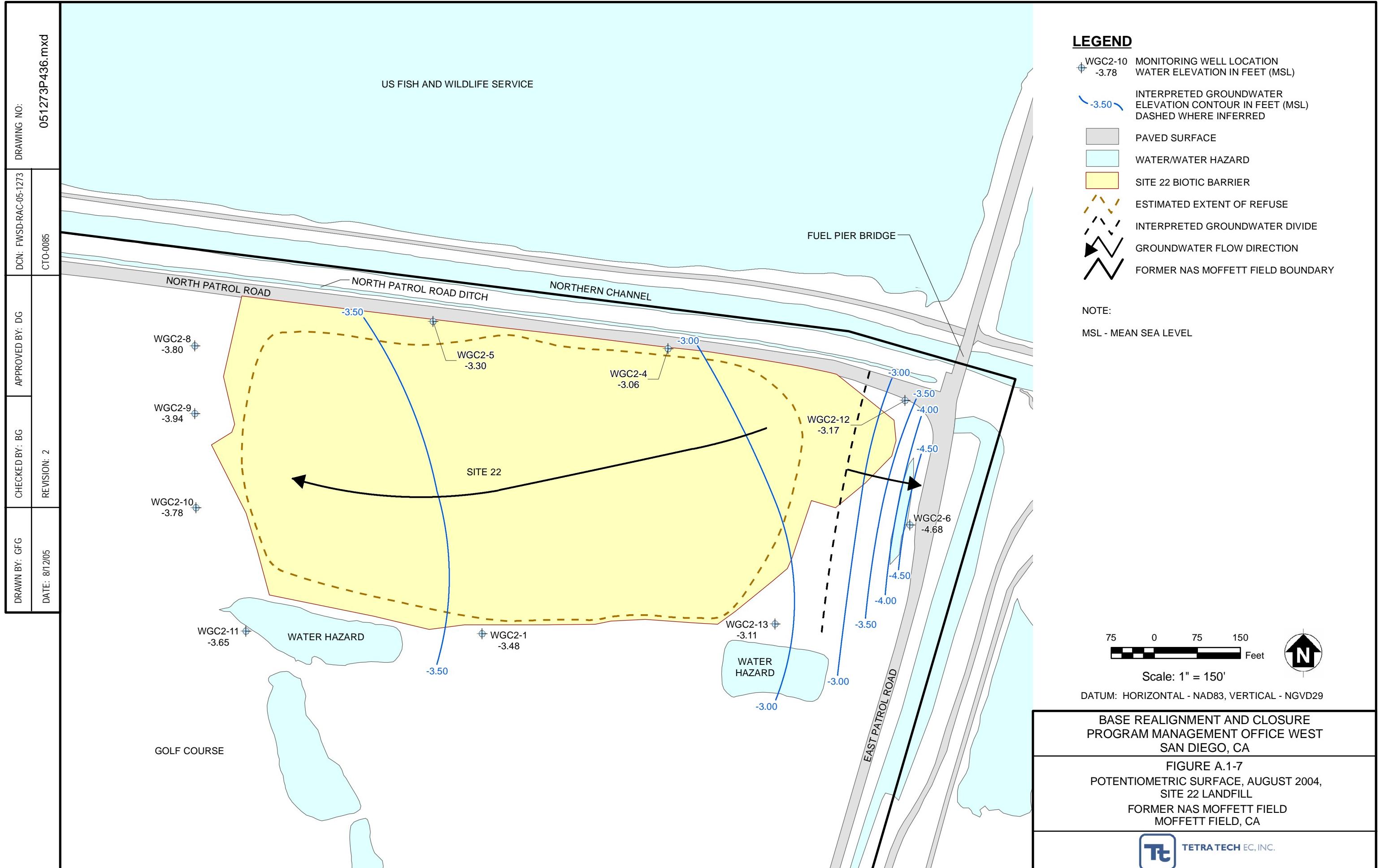


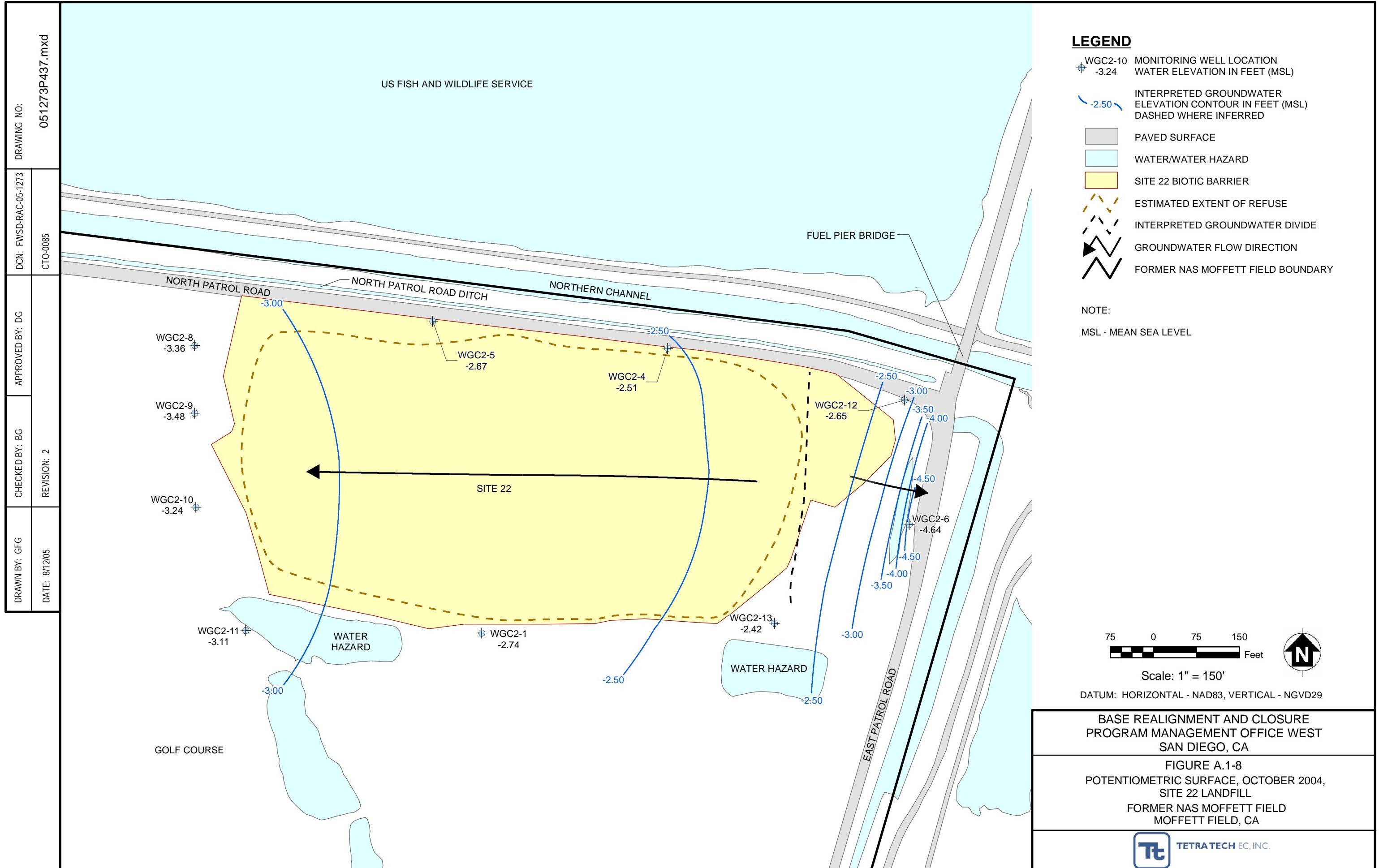












APPENDIX B

ANALYTICAL RESULTS FOR SITE 22 COCs
NOVEMBER 2003 THROUGH OCTOBER 2004

TABLE B-1

Page 1 of 4

CONCENTRATIONS OF VOCs IN GROUNDWATER
NOVEMBER 2003 THROUGH OCTOBER 2004
SITE 22 LANDFILL

Analyte	WGC2-1 2003/11/04 REG	WGC2-1 2003/12/11 REG	WGC2-1 2004/02/11 REG	WGC2-1 2004/03/16 REG	WGC2-1 2004/05/12 FD	WGC2-1 2004/05/12 REG	WGC2-1 2004/07/06 REG	WGC2-1 2004/08/31 REG	WGC2-1 2004/10/27 REG	WGC2-4 2003/11/05 FD	WGC2-4 2003/11/05 REG	WGC2-4 2003/12/11 REG
BENZENE	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	2 U
CHLOROBENZENE	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	2 U
CHLOROFORM	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1.2	0.86 J	2 U
CIS-1,2-DICHLOROETHENE	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	2 U
ETHYLBENZENE	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	2 U
TOLUENE	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	2 U
TRICHLOROETHENE	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	2 U
VINYL CHLORIDE	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	2 U
XYLENE (TOTAL)	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U	4 U

Analyte	WGC2-4 2004/02/04 REG	WGC2-4 2004/03/17 REG	WGC2-4 2004/05/13 REG	WGC2-4 2004/07/07 REG	WGC2-4 2004/09/01 REG	WGC2-4 2004/10/27 REG	WGC2-5 2003/11/05 REG	WGC2-5 2003/12/11 REG	WGC2-5 2004/02/03 REG	WGC2-5 2004/03/16 REG	WGC2-5 2004/05/13 REG	WGC2-5 2004/07/06 REG
BENZENE	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
CHLOROBENZENE	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
CHLOROFORM	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
CIS-1,2-DICHLOROETHENE	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
ETHYLBENZENE	1 U	1 U	1 UJ	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
TOLUENE	1 U	1 U	1 UJ	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
TRICHLOROETHENE	1 U	1 U	1 UJ	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
VINYL CHLORIDE	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
XYLENE (TOTAL)	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U

TABLE B-1

Page 2 of 4

CONCENTRATIONS OF VOCs IN GROUNDWATER
NOVEMBER 2003 THROUGH OCTOBER 2004
SITE 22 LANDFILL

Analyte	WGC2-5 2004/08/31 FD	WGC2-5 2004/08/31 REG	WGC2-5 2004/10/27 REG	WGC2-6 2003/11/05 REG	WGC2-6 2003/12/11 REG	WGC2-6 2004/02/03 REG	WGC2-6 2004/03/16 FD	WGC2-6 2004/03/16 REG	WGC2-6 2004/05/13 REG	WGC2-6 2004/07/07 REG	WGC2-6 2004/09/01 REG	WGC2-6 2004/10/25 REG
BENZENE	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
CHLOROBENZENE	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
CHLOROFORM	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
CIS-1,2-DICHLOROETHENE	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
ETHYLBENZENE	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U	1 U
TOLUENE	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U	1 U
TRICHLOROETHENE	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U	1 U
VINYL CHLORIDE	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
XYLENE (TOTAL)	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U

Analyte	WGC2-8 2003/11/05 REG	WGC2-8 2003/12/11 REG	WGC2-8 2004/02/04 REG	WGC2-8 2004/03/17 REG	WGC2-8 2004/05/13 REG	WGC2-8 2004/07/07 REG	WGC2-8 2004/09/01 REG	WGC2-8 2004/10/28 REG	WGC2-9 2003/11/10 REG	WGC2-9 2003/12/11 FD	WGC2-9 2003/12/11 REG	WGC2-9 2004/02/04 FD
BENZENE	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
CHLOROBENZENE	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
CHLOROFORM	0.97 J	1 U	1 U	1 U	1 U	1 U	1 U	1 U	6.7	3.6	3.7	6.9
CIS-1,2-DICHLOROETHENE	0.27 J	1 U	0.24 J	0.21 J	0.23 J	1 U	1 U	0.22 J	1 U	1 U	1 U	1 U
ETHYLBENZENE	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U	1 U	1 U	1 U	1 U	1 U
TOLUENE	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U	1 U	1 U	1 U	1 U
TRICHLOROETHENE	1.6	1.3 J	1.6	1.8	1.8 J	1.3	1.5	1.7	0.39 J	0.32 J	0.33 J	0.55 J
VINYL CHLORIDE	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
XYLENE (TOTAL)	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U

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**CONCENTRATIONS OF VOCs IN GROUNDWATER
NOVEMBER 2003 THROUGH OCTOBER 2004
SITE 22 LANDFILL**

Analyte	WGC2-9 2004/02/04 REG	WGC2-9 2004/03/17 REG	WGC2-9 2004/05/13 REG	WGC2-9 2004/07/07 REG	WGC2-9 2004/09/01 REG	WGC2-9 2004/10/27 REG	WGC2-10 2003/11/04 REG	WGC2-10 2003/12/11 REG	WGC2-10 2004/02/04 REG	WGC2-10 2004/03/16 REG	WGC2-10 2004/05/13 REG	WGC2-10 2004/07/06 FD
BENZENE	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
CHLOROBENZENE	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
CHLOROFORM	7	5.4	5.1	3.8	3.7	3.7	1 U	1 U	1 U	1 U	1 U	1 U
CIS-1,2-DICHLOROETHENE	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
ETHYLBENZENE	1 U	1 U	1 UJ	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U
TOLUENE	1 U	1 U	1 UJ	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U
TRICHLOROETHENE	0.55 J	0.52 J	0.43 J	0.32 J	0.39 J	0.48 J	1 U	1 U	1 U	1 U	1 UJ	1 U
VINYL CHLORIDE	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
XYLENE (TOTAL)	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U

Analyte	WGC2-10 2004/07/06 REG	WGC2-10 2004/08/30 REG	WGC2-10 2004/10/25 REG	WGC2-11 2003/11/06 REG	WGC2-11 2003/12/11 REG	WGC2-11 2004/02/04 REG	WGC2-11 2004/03/16 REG	WGC2-11 2004/05/13 REG	WGC2-11 2004/07/07 REG	WGC2-11 2004/08/30 REG	WGC2-11 2004/10/27 REG	WGC2-12 2003/11/05 REG
BENZENE	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
CHLOROBENZENE	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
CHLOROFORM	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
CIS-1,2-DICHLOROETHENE	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
ETHYLBENZENE	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U	1 U	1 U
TOLUENE	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U	1 U	1 U
TRICHLOROETHENE	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 UJ	1 U	1 U	1 U	1 U
VINYL CHLORIDE	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
XYLENE (TOTAL)	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U

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**CONCENTRATIONS OF VOCs IN GROUNDWATER
NOVEMBER 2003 THROUGH OCTOBER 2004
SITE 22 LANDFILL**

Analyte	WGC2-12 2003/12/11 REG	WGC2-12 2004/02/03 REG	WGC2-12 2004/03/16 REG	WGC2-12 2004/05/13 REG	WGC2-12 2004/07/07 REG	WGC2-12 2004/08/31 REG	WGC2-12 2004/10/25 REG	WGC2-12 2004/10/25 FD	WGC2-13 2003/11/05 REG	WGC2-13 2003/12/11 REG	WGC2-13 2004/02/04 REG	WGC2-13 2004/03/17 REG
BENZENE	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	2 U	1 U	1 U
CHLOROBENZENE	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	2 U	1 U	1 U
CHLOROFORM	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	0.35 J	2 U	0.22 J	1 U
CIS-1,2-DICHLOROETHENE	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	2 U	1 U	1 U
ETHYLBENZENE	1 U	1 U	1 U	1 UJ	1 U	1 U	1 U	1 U	1 U	2 U	1 U	1 U
TOLUENE	1 U	1 U	1 U	1 UJ	1 U	1 U	1 U	1 U	0.22 J	2 U	1 U	1 U
TRICHLOROETHENE	1 U	1 U	1 U	1 UJ	1 U	1 U	1 U	1 U	1 U	2 U	1 U	1 U
VINYL CHLORIDE	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	2 U	1 U	1 U
XYLENE (TOTAL)	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U	4 U	3 U	3 U

Analyte	WGC2-13 2004/05/13 REG	WGC2-13 2004/07/07 REG	WGC2-13 2004/09/01 REG	WGC2-13 2004/10/27 REG
BENZENE	1 U	1 U	1 U	1 U
CHLOROBENZENE	1 U	1 U	1 U	1 U
CHLOROFORM	1 U	1 U	1 U	1 U
CIS-1,2-DICHLOROETHENE	1 U	1 U	1 U	1 U
ETHYLBENZENE	1 UJ	1 U	1 U	1 U
TOLUENE	1 UJ	1 U	1 U	1 U
TRICHLOROETHENE	1 UJ	1 U	1 U	1 U
VINYL CHLORIDE	1 U	1 U	1 U	1 U
XYLENE (TOTAL)	3 U	3 U	3 U	3 U

Notes:

All concentrations are in mg/L.

Abbreviations and Acronyms:

μg/L - micrograms per liter

FD - field duplicate

J - estimated value below the sample quantitation limit

REG - regular sample

U - not detected above the method detection limit

VOC - volatile organic compound

TABLE B-2

**CONCENTRATIONS OF PESTICIDES IN GROUNDWATER
NOVEMBER 2003 THROUGH OCTOBER 2004
SITE 22 LANDFILL**

Analyte	WGC2-1 2003/11/04 REG	WGC2-1 2003/12/11 REG	WGC2-1 2004/02/11 REG	WGC2-1 2004/03/16 REG	WGC2-1 2004/05/12 FD	WGC2-1 2004/05/12 REG	WGC2-1 2004/07/06 REG	WGC2-1 2004/08/31 REG	WGC2-1 2004/10/27 REG	WGC2-4 2003/11/05 FD	WGC2-4 2003/11/05 REG	WGC2-4 2003/12/11 REG
ALDRIN	0.047 U	0.047 U	0.047 U	0.047 U	0.047 U	0.048 U	0.048 U	0.047 U	0.047 U	0.047 U	0.047 U	0.047 U
GAMMA-BHC (LINDANE)	0.047 U	0.047 U	0.047 U	0.047 UJ	0.047 U	0.048 U	0.048 U	0.047 U	0.047 U	0.047 U	0.047 U	0.047 U

Analyte	WGC2-4 2004/02/04 REG	WGC2-4 2004/03/17 REG	WGC2-4 2004/05/13 REG	WGC2-4 2004/07/07 REG	WGC2-4 2004/09/01 REG	WGC2-4 2004/10/27 REG	WGC2-5 2003/11/05 REG	WGC2-5 2003/12/11 REG	WGC2-5 2004/02/03 REG	WGC2-5 2004/03/16 REG	WGC2-5 2004/05/13 REG	WGC2-5 2004/07/06 REG
ALDRIN	0.048 U	0.047 U	0.047 U	0.048 U	0.047 U							
GAMMA-BHC (LINDANE)	0.048 U	0.047 UJ	0.047 U	0.048 U	0.047 UJ	0.047 U	0.047 U					

Analyte	WGC2-5 2004/08/31 FD	WGC2-5 2004/08/31 REG	WGC2-5 2004/10/27 REG	WGC2-6 2003/11/05 REG	WGC2-6 2003/12/11 REG	WGC2-6 2004/02/03 REG	WGC2-6 2004/03/16 FD	WGC2-6 2004/03/16 REG	WGC2-6 2004/05/13 REG	WGC2-6 2004/07/07 REG	WGC2-6 2004/09/01 REG	WGC2-6 2004/10/25 REG
ALDRIN	0.047 U	0.047 U	0.047 U	0.047 U	0.047 U	0.05 U	0.047 U	0.047 U	0.047 U	0.049 U	0.047 U	0.047 U
GAMMA-BHC (LINDANE)	0.047 U	0.047 U	0.047 U	0.047 U	0.047 U	0.05 U	0.047 UJ	0.047 UJ	0.047 U	0.049 U	0.047 U	0.047 U

TABLE B-2

**CONCENTRATIONS OF PESTICIDES IN GROUNDWATER
NOVEMBER 2003 THROUGH OCTOBER 2004
SITE 22 LANDFILL**

Analyte	WGC2-8 2003/11/05 REG	WGC2-8 2003/12/11 REG	WGC2-8 2004/02/04 REG	WGC2-8 2004/03/17 REG	WGC2-8 2004/05/13 REG	WGC2-8 2004/07/07 REG	WGC2-8 2004/09/01 REG	WGC2-8 2004/10/28 REG	WGC2-9 2004/11/10 REG	WGC2-9 2003/12/11 FD	WGC2-9 2003/12/11 REG	WGC2-9 2004/02/04 FD
ALDRIN	0.048 U	0.047 U	0.048 U	0.05 UJ	0.047 U	0.047 U	0.047 U	0.047 U	0.036 J	0.047 U	0.047 U	0.047 U
GAMMA-BHC (LINDANE)	0.048 U	0.047 U	0.048 U	0.05 UJ	0.047 U	0.047 U	0.047 U	0.047 U	0.042 J	0.047 U	0.047 U	0.047 U

Analyte	WGC2-9 2004/02/04 REG	WGC2-9 2004/03/17 REG	WGC2-9 2004/05/13 REG	WGC2-9 2004/07/07 REG	WGC2-9 2004/09/01 REG	WGC2-9 2004/10/27 REG	WGC2-10 2003/11/04 REG	WGC2-10 2003/12/11 REG	WGC2-10 2004/02/04 REG	WGC2-10 2004/03/16 REG	WGC2-10 2004/05/13 REG	WGC2-10 2004/07/06 FD
ALDRIN	0.047 U	0.049 U	0.047 U	0.047 U	0.048 U	0.047 U	0.047 U	0.047 U				
GAMMA-BHC (LINDANE)	0.047 U	0.049 UJ	0.047 U	0.047 U	0.048 U	0.047 UJ	0.047 U	0.047 U				

Analyte	WGC2-10 2004/07/06 REG	WGC2-10 2004/08/30 REG	WGC2-10 2004/10/25 REG	WGC2-11 2003/11/06 REG	WGC2-11 2003/12/11 REG	WGC2-11 2004/02/04 REG	WGC2-11 2004/03/16 REG	WGC2-11 2004/05/13 REG	WGC2-11 2004/07/07 REG	WGC2-11 2004/08/30 REG	WGC2-11 2004/10/27 REG	WGC2-12 2003/11/05 REG
ALDRIN	0.05 U	0.047 U	0.047 U	0.1	0.047 U	0.049 U						
GAMMA-BHC (LINDANE)	0.05 U	0.047 U	0.047 U	0.2	0.047 U	0.047 U	0.047 UJ	0.047 U	0.047 U	0.047 U	0.047 U	0.022 J

TABLE B-2

**CONCENTRATIONS OF PESTICIDES IN GROUNDWATER
NOVEMBER 2003 THROUGH OCTOBER 2004
SITE 22 LANDFILL**

Analyte	WGC2-12 2003/12/11 REG	WGC2-12 2004/02/03 REG	WGC2-12 2004/03/16 REG	WGC2-12 2004/05/13 REG	WGC2-12 2004/07/07 REG	WGC2-12 2004/08/31 REG	WGC2-12 2004/10/25 REG	WGC2-12 2004/10/25 FD	WGC2-13 2003/11/05 REG	WGC2-13 2003/12/11 REG	WGC2-13 2004/02/04 REG	WGC2-13 2004/03/17 REG
ALDRIN	0.047 U	0.05 U	0.047 U	0.047 U	0.047 U	0.048 U	0.047 U	0.047 U	0.047 U	0.047 U	0.047 U	0.049 U
GAMMA-BHC (LINDANE)	0.047 U	0.05 U	0.047 UJ	0.047 U	0.047 U	0.048 U	0.047 U	0.047 U	0.047 U	0.047 U	0.047 U	0.049 UJ

Analyte	WGC2-13 2004/05/13 REG	WGC2-13 2004/07/07 REG	WGC2-13 2004/09/01 REG	WGC2-13 2004/10/27 REG
ALDRIN	0.047 U	0.049 U	0.047 U	0.047 U
GAMMA-BHC (LINDANE)	0.047 U	0.049 U	0.047 U	0.047 U

Notes:

All concentrations are in $\mu\text{g/L}$.

Abbreviations and Acronyms:

$\mu\text{g/L}$ - micrograms per liter

BHC - benzene hexachloride

FD - field duplicate

J - estimated value below the sample quantitation limit

REG - regular sample

U - not detected above the method detection limit

TABLE B-3

**CONCENTRATIONS OF SVOCs IN GROUNDWATER
SEPTEMBER 1994 THROUGH OCTOBER 2004
SITE 22 LANDFILL**

Analyte	WGC2-1 1994/09/19 REG	WGC2-1 1994/11/30 REG	WGC2-1 1995/06/07 REG	WGC2-1 1998/04/07 REG	WGC2-1 2003/11/04 REG	WGC2-1 2003/12/11 REG	WGC2-1 2004/02/11 REG	WGC2-1 2004/03/16 REG	WGC2-1 2004/05/12 FD	WGC2-1 2004/05/12 REG	WGC2-1 2004/07/06 REG	WGC2-1 2004/08/31 REG
1,4-DICHLOROBENZENE	10 U	10 U	10 U	na	9.4 UJ	9.4 U	10 U	9.6 U	9.4 UJ	9.4 UJ	9.4 U	9.4 U
2-METHYLNAPHTHALENE	10 U	10 U	10 U	10 U	9.4 UJ	9.4 U	10 U	9.6 U	9.4 UJ	9.4 UJ	9.4 U	9.4 U
3/4-METHYLPHENOL	10 U	10 U	10 U	10 U	9.4 UJ	9.4 U	10 U	9.6 U	9.4 UJ	9.4 UJ	9.4 U	9.4 U
BIS(2-ETHYLHEXYL)PHTHALATE	37 UJ-B	2 U-B	10 U	4 U	19 UJ	19 U	20 U	19 U	19 UJ	19 UJ	19 U	19 U
CARBAZOLE	10 U	10 U	10 U	10 U	9.4 UJ	9.4 U	10 U	9.6 U	9.4 UJ	9.4 UJ	9.4 U	9.4 U
DIBENZOFURAN	10 U	10 U	10 U	10 U	9.4 UJ	9.4 U	10 U	9.6 U	9.4 UJ	9.4 UJ	9.4 U	9.4 U
DIETHYLPHthalate	10 U	10 U	10 U	10 U	19 UJ	19 U	20 U	19 U	19 UJ	19 UJ	19 U	19 U
FLUORENE	10 U	10 U	10 U	10 U	9.4 UJ	9.4 U	10 U	9.6 U	9.4 UJ	9.4 UJ	9.4 U	9.4 U
NAPHTHALENE	10 U	10 U	10 U	10 U	9.4 UJ	9.4 U	10 U	9.6 U	9.4 UJ	9.4 UJ	9.4 U	9.4 U

Analyte	WGC2-1 2004/10/27 REG	WGC2-4 1994/09/21 REG	WGC2-4 1994/11/30 REG	WGC2-4 1995/03/21 REG	WGC2-4 1995/06/07 REG	WGC2-4 1998/04/20 REG	WGC2-4 2003/11/05 FD	WGC2-4 2003/11/05 REG	WGC2-4 2003/12/11 REG	WGC2-4 2004/02/04 REG	WGC2-4 2004/03/17 REG	WGC2-4 2004/05/13 REG
1,4-DICHLOROBENZENE	9.4 U	10 U	10 U	10 U	10 U	na	9.4 U	9.4 U	9.4 U	9.4 U	9.6 U	9.4 U
2-METHYLNAPHTHALENE	9.4 U	10 U	10 U	10 U	10 U	10 U	9.4 U	9.4 U	9.4 U	9.4 U	9.6 U	9.4 U
3/4-METHYLPHENOL	9.4 U	10 U	10 U	10 U	10 U	10 U	9.4 U	9.4 U	9.4 U	9.4 U	9.6 U	9.4 U
BIS(2-ETHYLHEXYL)PHTHALATE	19 U	8 UB	6 UB	10 UB	10 UJB	4 U	19 U	19 U	19 U	19 U	19 U	19 U
CARBAZOLE	9.4 U	10 U	10 U	10 U	10 U	10 U	9.4 U	9.4 U	9.4 U	9.4 U	9.6 U	9.4 U
DIBENZOFURAN	9.4 U	10 U	10 U	10 U	10 U	10 U	9.4 U	9.4 U	9.4 U	9.4 U	9.6 U	9.4 U
DIETHYLPHthalate	19 U	10 U	19 U	19 U	19 U	19 U	19 U	19 U				
FLUORENE	9.4 U	10 U	10 U	10 U	10 U	10 U	9.4 U	9.4 U	9.4 U	9.4 U	9.6 U	9.4 U
NAPHTHALENE	9.4 U	10 U	10 U	10 U	10 U	10 U	9.4 U	9.4 U	9.4 U	9.4 U	9.6 U	9.4 U

TABLE B-3

**CONCENTRATIONS OF SVOCs IN GROUNDWATER
SEPTEMBER 1994 THROUGH OCTOBER 2004
SITE 22 LANDFILL**

Analyte	WGC2-4 2004/07/07 REG	WGC2-4 2004/09/01 REG	WGC2-4 2004/10/27 REG	WGC2-5 1994/09/16 REG	WGC2-5 1994/11/29 REG	WGC2-5 1995/03/21 REG	WGC2-5 1995/06/07 REG	WGC2-5 1998/04/20 REG	WGC2-5 2003/11/05 REG	WGC2-5 2003/12/11 REG	WGC2-5 2004/02/03 REG	WGC2-5 2004/03/16 REG
1,4-DICHLOROBENZENE	9.9 U	9.4 U	9.4 U	10 U	10 U	10 U	10 U	na	9.4 U	9.4 U	9.4 U	10 U
2-METHYLNAPHTHALENE	9.9 U	9.4 U	9.4 U	10 U	10 U	10 U	10 U	10 U	9.4 U	9.4 U	9.4 U	10 U
3/4-METHYLPHENOL	9.9 U	9.4 U	9.4 U	10 U	10 U	10 U	10 U	10 U	9.4 U	9.4 U	9.4 U	10 U
BIS(2-ETHYLHEXYL)PHTHALATE	20 U	19 U	19 U	1 UB	3 UB	13 UJB	10 U	15	19 U	19 U	19 U	20 U
CARBAZOLE	9.9 U	9.4 U	9.4 U	10 U	10 UJK	10 U	10 U	10 U	9.4 U	9.4 U	9.4 U	10 U
DIBENZOFURAN	9.9 U	9.4 U	9.4 U	10 U	10 U	10 U	10 U	10 U	9.4 U	9.4 U	9.4 U	10 U
DIETHYLPHthalate	20 U	19 U	19 U	10 U	19 U	19 U	19 U	20 U				
FLUORENE	9.9 U	9.4 U	9.4 U	10 U	10 U	10 U	10 U	10 U	9.4 U	9.4 U	9.4 U	10 U
NAPHTHALENE	9.9 U	9.4 U	9.4 U	10 U	10 U	10 U	10 U	10 U	9.4 U	9.4 U	9.4 U	10 U

Analyte	WGC2-5 2004/05/13 REG	WGC2-5 2004/07/06 REG	WGC2-5 2004/08/31 FD	WGC2-5 2004/08/31 REG	WGC2-5 2004/10/27 REG	WGC2-6 1994/09/19 REG	WGC2-6 1994/11/30 REG	WGC2-6 1995/03/20 REG	WGC2-6 1995/06/09 REG	WGC2-6 1998/04/06 FD	WGC2-6 1998/04/06 REG	WGC2-6 2003/11/05 REG
1,4-DICHLOROBENZENE	9.4 U	9.7 U	9.4 U	9.4 U	9.4 U	10 U	10 U	10 U	10 U	na	na	9.4 U
2-METHYLNAPHTHALENE	9.4 U	9.7 U	9.4 U	9.4 U	9.4 U	10 U	10 U	10 U	10 U	10 U	10 U	9.4 U
3/4-METHYLPHENOL	9.4 U	9.7 U	9.4 U	9.4 U	9.4 U	10 U	10 U	10 U	10 U	10 U	10 U	9.4 U
BIS(2-ETHYLHEXYL)PHTHALATE	19 U	19 U	19 U	19 U	19 U	18 UJB	3 UB	4 UB	3 UB	4 U	4 U	19 U
CARBAZOLE	9.4 U	9.7 U	9.4 U	9.4 U	9.4 U	10 U	10 U	10 UJK	10 U	10 U	10 U	9.4 U
DIBENZOFURAN	9.4 U	9.7 U	9.4 U	9.4 U	9.4 U	10 U	10 U	10 U	10 U	10 U	10 U	9.4 U
DIETHYLPHthalate	19 U	19 U	19 U	19 U	19 U	10 U	10 U	19 U				
FLUORENE	9.4 U	9.7 U	9.4 U	9.4 U	9.4 U	10 U	10 U	10 U	10 U	10 U	10 U	9.4 U
NAPHTHALENE	9.4 U	9.7 U	9.4 U	9.4 U	9.4 U	10 U	10 U	10 U	10 U	10 U	10 U	9.4 U

TABLE B-3

**CONCENTRATIONS OF SVOCs IN GROUNDWATER
SEPTEMBER 1994 THROUGH OCTOBER 2004
SITE 22 LANDFILL**

Analyte	WGC2-6 2003/12/11 REG	WGC2-6 2004/02/03 REG	WGC2-6 2004/03/16 FD	WGC2-6 2004/03/16 REG	WGC2-6 2004/05/13 REG	WGC2-6 2004/07/07 REG	WGC2-6 2004/09/01 REG	WGC2-6 2004/10/25 REG	WGC2-8 2003/11/05 REG	WGC2-8 2003/12/11 REG	WGC2-8 2004/02/04 REG	WGC2-8 2004/03/17 REG
1,4-DICHLOROBENZENE	9.4 U	10 U	9.4 U	9.5 U	9.4 U	9.4 U	9.4 U	9.4 U	9.5 U	9.4 U	9.4 U	9.6 U
2-METHYLNAPHTHALENE	9.4 U	10 U	9.4 U	9.5 U	9.4 U	9.4 U	9.4 U	9.4 U	9.5 U	9.4 U	9.4 U	9.6 U
3/4-METHYLPHENOL	9.4 U	10 U	9.4 U	9.5 U	9.4 U	9.4 U	9.4 U	9.4 U	9.5 U	9.4 U	9.4 U	9.6 U
BIS(2-ETHYLHEXYL)PHTHALATE	19 U	20 U	19 U	19 U	19 U	19 U	11 J	19 U				
CARBAZOLE	9.4 U	10 U	9.4 U	9.5 U	9.4 U	9.4 U	9.4 U	9.4 U	9.5 U	9.4 U	9.4 U	9.6 U
DIBENZOFURAN	9.4 U	10 U	9.4 U	9.5 U	9.4 U	9.4 U	9.4 U	9.4 U	9.5 U	9.4 U	9.4 U	9.6 U
DIETHYLPHthalate	19 U	20 U	19 U	19 U	19 U	19 U	19 U	19 U	19 U	19 U	19 U	19 U
FLUORENE	9.4 U	10 U	9.4 U	9.5 U	9.4 U	9.4 U	9.4 U	9.4 U	9.5 U	9.4 U	9.4 U	9.6 U
NAPHTHALENE	9.4 U	10 U	9.4 U	9.5 U	9.4 U	9.4 U	9.4 U	9.4 U	9.5 U	9.4 U	9.4 U	9.6 U

Analyte	WGC2-8 2004/05/13 REG	WGC2-8 2004/07/07 REG	WGC2-8 2004/09/01 REG	WGC2-8 2004/10/28 REG	WGC2-9 2003/11/10 REG	WGC2-9 2003/12/11 FD	WGC2-9 2003/12/11 REG	WGC2-9 2004/02/04 FD	WGC2-9 2004/02/04 REG	WGC2-9 2004/03/17 REG	WGC2-9 2004/05/13 REG	WGC2-9 2004/07/07 REG
1,4-DICHLOROBENZENE	9.4 U	9.4 U	9.4 U	9.5 U	9.6 U	9.4 U	9.4 U	9.4 U				
2-METHYLNAPHTHALENE	9.4 U	9.4 U	9.4 U	9.5 U	9.6 U	9.4 U	9.4 U	9.4 U				
3/4-METHYLPHENOL	9.4 U	9.4 U	9.4 U	9.5 U	9.6 U	9.4 U	9.4 U	9.4 U				
BIS(2-ETHYLHEXYL)PHTHALATE	19 U	19 U	19 U	19 U	19 U	19 U	19 U	19 U				
CARBAZOLE	9.4 U	9.4 U	9.4 U	9.5 U	9.6 U	9.4 U	9.4 U	9.4 U				
DIBENZOFURAN	9.4 U	9.4 U	9.4 U	9.5 U	9.6 U	9.4 U	9.4 U	9.4 U				
DIETHYLPHthalate	19 U	19 U	19 U	19 U	19 U	19 U	19 U	19 U				
FLUORENE	9.4 U	9.4 U	9.4 U	9.5 U	9.6 U	9.4 U	9.4 U	9.4 U				
NAPHTHALENE	9.4 U	9.4 U	9.4 U	9.5 U	9.6 U	9.4 U	9.4 U	9.4 U				

TABLE B-3

**CONCENTRATIONS OF SVOCs IN GROUNDWATER
SEPTEMBER 1994 THROUGH OCTOBER 2004
SITE 22 LANDFILL**

Analyte	WGC2-9 2004/09/01 REG	WGC2-9 2004/10/27 REG	WGC2-10 2003/11/04 REG	WGC2-10 2003/12/11 REG	WGC2-10 2004/02/04 REG	WGC2-10 2004/03/16 REG	WGC2-10 2004/05/13 REG	WGC2-10 2004/07/06 FD	WGC2-10 2004/07/06 REG	WGC2-10 2004/08/30 REG	WGC2-10 2004/10/25 REG	WGC2-11 2003/11/06 REG
1,4-DICHLOROBENZENE	9.4 U	9.4 U	9.4 UJ	9.4 U	9.4 U	9.4 U	9.4 U	9.6 U	10 U	9.4 UJ	9.4 U	9.5 U
2-METHYLNAPHTHALENE	9.4 U	9.4 U	9.4 UJ	9.4 U	9.4 U	9.4 U	9.4 UJ	9.6 U	10 U	9.4 UJ	9.4 U	9.5 U
3/4-METHYLPHENOL	9.4 U	9.4 U	9.4 UJ	9.4 U	9.4 U	9.4 U	9.4 U	9.6 U	10 U	9.4 U	9.4 U	9.5 U
BIS(2-ETHYLHEXYL)PHTHALATE	19 U	19 U	19 UJ	19 U	19 U	19 U	19 U	19 U	20 U	19 UJ	19 U	19 U
CARBAZOLE	9.4 U	9.4 U	9.4 UJ	9.4 U	9.4 U	9.4 U	9.4 U	9.6 U	10 U	9.4 UJ	9.4 U	9.5 U
DIBENZOFURAN	9.4 U	9.4 U	9.4 UJ	9.4 U	9.4 U	9.4 U	9.4 U	9.6 U	10 U	9.4 UJ	9.4 U	9.5 U
DIETHYLPHthalate	19 U	19 U	19 UJ	19 U	19 U	19 U	19 U	19 U	20 U	19 UJ	19 U	19 U
FLUORENE	9.4 U	9.4 U	9.4 UJ	9.4 U	9.4 U	9.4 U	9.4 U	9.6 U	10 U	9.4 UJ	9.4 U	9.5 U
NAPHTHALENE	9.4 U	9.4 U	9.4 UJ	9.4 U	9.4 U	9.4 U	9.4 U	9.6 U	10 U	9.4 UJ	9.4 U	9.5 U

Analyte	WGC2-11 2003/12/11 REG	WGC2-11 2004/02/04 REG	WGC2-11 2004/03/16 REG	WGC2-11 2004/05/13 REG	WGC2-11 2004/07/07 REG	WGC2-11 2004/08/30 REG	WGC2-11 2004/10/27 REG	WGC2-12 2003/11/05 REG	WGC2-12 2003/12/11 REG	WGC2-12 2004/02/03 REG	WGC2-12 2004/03/16 REG	WGC2-12 2004/05/13 REG
1,4-DICHLOROBENZENE	9.4 U	9.5 U	9.4 U	9.8 U	9.5 U	9.4 U						
2-METHYLNAPHTHALENE	9.4 U	9.5 U	9.4 U	9.8 U	9.5 U	9.4 U						
3/4-METHYLPHENOL	9.4 U	9.5 U	9.4 U	9.8 U	9.5 U	9.4 U						
BIS(2-ETHYLHEXYL)PHTHALATE	19 U	20 U	19 U	19 U								
CARBAZOLE	9.4 U	9.5 U	9.4 U	9.8 U	9.5 U	9.4 U						
DIBENZOFURAN	9.4 U	9.5 U	9.4 U	9.8 U	9.5 U	9.4 U						
DIETHYLPHthalate	19 U	20 U	19 U	19 U								
FLUORENE	9.4 U	9.5 U	9.4 U	9.8 U	9.5 U	9.4 U						
NAPHTHALENE	9.4 U	9.5 U	9.4 U	9.8 U	9.5 U	9.4 U						

TABLE B-3

**CONCENTRATIONS OF SVOCs IN GROUNDWATER
SEPTEMBER 1994 THROUGH OCTOBER 2004
SITE 22 LANDFILL**

Analyte	WGC2-12 2004/07/07 REG	WGC2-12 2004/08/31 REG	WGC2-12 2004/10/25 REG	WGC2-12 2004/10/25 FD	WGC2-13 2003/11/05 REG	WGC2-13 2003/12/11 REG	WGC2-13 2004/02/04 REG	WGC2-13 2004/03/17 REG	WGC2-13 2004/05/13 REG	WGC2-13 2004/07/07 REG	WGC2-13 2004/09/01 REG	WGC2-13 2004/10/27 REG
1,4-DICHLOROBENZENE	9.4 U	9.4 U	9.4 U	9.4 U	9.4 U	9.4 U	9.4 U	9.5 U	9.4 U	9.4 U	9.4 U	9.4 U
2-METHYLNAPHTHALENE	9.4 U	9.4 U	9.4 U	9.4 U	9.4 U	9.4 U	9.4 U	9.5 U	9.4 U	9.4 U	9.4 U	9.4 U
4-METHYLPHENOL	9.4 U	9.4 U	9.4 U	9.4 U	9.4 U	9.4 U	9.4 U	9.5 U	9.4 U	9.4 U	9.4 U	9.4 U
BIS(2-ETHYLHEXYL)PHTHALATE	19 U	19 U	19 U	19 U	19 U	19 U	19 U	19 U	19 U	19 U	19 U	19 U
CARBAZOLE	9.4 U	9.4 U	9.4 U	9.4 U	9.4 U	9.4 U	9.4 U	9.5 U	9.4 U	9.4 U	9.4 U	9.4 U
DIBENZOFURAN	9.4 U	9.4 U	9.4 U	9.4 U	9.4 U	9.4 U	9.4 U	9.5 U	9.4 U	9.4 U	9.4 U	9.4 U
DIETHYLPHTHALATE	19 U	19 U	19 U	19 U	19 U	19 U	19 U	19 U	19 U	19 U	19 U	19 U
FLUORENE	9.4 U	9.4 U	9.4 U	9.4 U	9.4 U	9.4 U	9.4 U	9.5 U	9.4 U	9.4 U	9.4 U	9.4 U
NAPHTHALENE	9.4 U	9.4 U	9.4 U	9.4 U	9.4 U	9.4 U	9.4 U	9.5 U	9.4 U	9.4 U	9.4 U	9.4 U

Notes:

All concentrations are in mg/L.

Abbreviations and Acronyms:

mg/L - micrograms per liter

B - also detected in method blank

FD - field duplicate

J - estimated value below the sample quantitation limit

K - ununspecified data qualifer from previous contractor

na - not analyzed

REG - regular sample

SVOC - semivolatile organic compound

U - not detected above the method detection limit

APPENDIX C

SURROGATE SELECTION RATIONALE

**Base Realignment and Closure
Program Management Office West
1230 Columbia Street, Suite 1100
San Diego, California 92101**

**CONTRACT NO. N68711-98-D-5713
CTO No. 0085**

APPENDIX C

DRAFT

SURROGATE SELECTION RATIONALE

Revision 0

August 12, 2005

**FORMER NAVAL AIR STATION MOFFETT FIELD
MOFFETT FIELD, CALIFORNIA**

DCN: FWSD-RAC-05-1273



TETRA TECH EC, INC.

**1230 Columbia Street, Suite 500
San Diego, CA 92101**

SURROGATE SELECTION RATIONALE

Of the 20 constituents of concern (COCs) listed for the Site 22 Landfill (Table C-1), 5 did not have surface water screening values reported in any of the four sources consulted (such as the U.S. Environmental Protection Agency, Department of Toxic Substances Control, National Oceanic and Atmospheric Administration, or Oak Ridge National Laboratory). Therefore, surrogates were evaluated and selected for use as screening values.

Surrogates were selected following the protocol discussed in Section 4.1.1 of the Post-Construction Operations, Maintenance, and Monitoring Plan. Two classes of surrogates were used in the following order of priority: structural isomers, and homomorphs. Structural isomers are identical in chemical formula and molecular weight. They differ only in the positions of the chemical constituents. For example, 2-methylphenol has the same chemical formula and weight as 4-methylphenol; the only difference is the location of the methyl group on the compound. Therefore, 2-methylphenol was used as a surrogate for 4-methylphenol, because it is a structural isomer.

If there were no structurally identical compounds, then compounds were evaluated to see if there were any that were homomorphs (similar structure). For example, 1,2-dichloroethene would be selected as a surrogate for vinyl chloride due to structural similarity. The primary difference being that 1,2-dichloroethene has two chlorine molecules versus the one that vinyl chloride has. Both compounds have similar toxicity values.

In the case where two analytes are considered for the surrogate selection, reported screening values were then considered. The analyte with the more conservative toxicity value and screening level would be selected as the surrogate. The types of chemical constituents, bonding patterns, toxicity values, and screening levels would be compared to identify the most appropriate surrogate. Table C-1 details how each of the surrogates was selected for the five COCs and the rationale for their selection.

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TABLE C-1

**SURROGATE RATIONALE FOR CONSTITUENTS OF CONCERN, SITE 22
FORMER NAS MOFFETT FIELD**

COC	Surrogate	Rationale for Selecting Surrogate
VOCs		
cis-1,2-Dichloroethene	1,2-Dichloroethene	1,2-Dichloroethene and cis-1,2-dichloroethene are structural isomers. 1,2-Dichloroethene is the only structural isomer with reported screening values. The chemical formula of both is $C_2H_2Cl_2$, and both have a molecular weight of 96.94.
Xylene (Total)	m-Xylene	m-Xylene and m,p-xylene are structural isomers. m-Xylene is the only structural isomer with reported screening values. The chemical formula for both is C_8H_{10} , and both have a molecular weight of 106.17.
Vinyl chloride	1,2-Dichloroethene	1,2-Dichloroethene is structurally similar to vinyl chloride. They differ only in that vinyl chloride has one chlorine and 1,2-dichloroethene has two. The 14-day LC ₅₀ toxicity values were compared, and they are similar. 1,2-Dichloroethene is the only structurally similar COC with reported screening values.
SVOCs		
4-Methylphenol	2-Methylphenol	2-Methylphenol and 4-methylphenol are structural isomers. 2-Methylphenol is the only isomer with reported screening values. The chemical formula of both is C_7H_8O , and both have a molecular weight of 108.14.
Carbazole	Dibenzofuran	Dibenzofuran is structurally similar to carbazole. They both have two benzene rings, but differ in constituents. The 14-day LC ₅₀ toxicity values were compared, and they are similar. Dibenzofuran is the only structurally similar COC with reported screening values.

Notes:

⁽¹⁾ 14-day LC₅₀ = The concentration of a chemical that is lethal to 50 percent of the test organisms after 14 days of exposure.

The LC₅₀s used in this evaluation are based on measured and estimated values from EPA's ECOSAR program.

Abbreviations and Acronyms:

COC - constituent of concern

EPA - U.S. Environmental Protection Agency

NAS - Naval Air Station

SVOC - semivolatile organic compound

VOC - volatile organic compound

APPENDIX D

ATTENUATION FACTORS

**Base Realignment and Closure
Program Management Office West
1230 Columbia Street, Suite 1100
San Diego, California 92101**

**CONTRACT NO. N68711-98-D-5713
CTO No. 0085**

**APPENDIX D
DRAFT
ATTENUATION FACTORS
Revision 0
August 12, 2005**

**FORMER NAVAL AIR STATION MOFFETT FIELD
MOFFETT FIELD, CALIFORNIA**

DCN: FWSD-RAC-05-1273



TETRA TECH EC, INC.

**1230 Columbia Street, Suite 500
San Diego, CA 92101**

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Potentiometric Surface Map, Area East of the Runways,
Upper A Aquifer, March 2004

D.4-2

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ABBREVIATIONS AND ACRONYMS

µg/L	micrograms per liter
AF	attenuation factor
AT123D	Analytical Transient 1-, 2-, 3-Dimensional
BHC	benzene hexachloride
CCL	calculated concentration limit
cm/sec	centimeters per second
COC	constituent of concern
EPA	U.S. Environmental Protection Agency
f _{oc}	fraction organic carbon
ft/ft	foot per foot
hrs	hours
K _{oc}	soil-water partitioning coefficient
m ³ /kg	cubic meter per kilogram
mL/g	milliters per gram
NAS	Naval Air Station
OMMP	Operations, Maintenance, and Monitoring Plan
POE	point of exposure
ROD	Record of Decision
SVOC	semivolatile organic compound
TCE	trichloroethene
TtFW	Tetra Tech FW, Inc.
VOC	volatile organic compound

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1.0 INTRODUCTION

The Department of the Navy (Navy) is conducting environmental restoration activities at Former Naval Air Station Moffett Field, Moffett Field, California. Tetra Tech FW, Inc. (TtFW) received Contract Task Order No. 0085 from the Navy, which includes monitoring, maintenance, and reporting for a closed solid waste landfill called the Site 22 Landfill.

A Record of Decision (ROD) (Navy, 2002), requires the Navy to develop a groundwater monitoring program, which includes concentration limits for constituents of concern (COCs) at Site 22. To fulfill the requirements of the ROD and the applicable regulations (California Code of Regulations, Title 27), a Post-Construction Operations, Maintenance, and Monitoring Plan Addendum was prepared, of which, this appendix is a part, to prescribe a groundwater evaluation process. Part of the groundwater evaluation process is development of the calculated concentration limits (CCLs). At Site 22, there are no applicable or appropriate regulatory criteria to compare groundwater concentrations to, based on the current groundwater use and exposure pathways. Therefore, CCLs were developed using an attenuation factor (AF) applied to the appropriate screening criteria. The AF is used to prorate ambient groundwater concentrations for comparison to surface water screening criteria, which represent the closest point of exposure (POE).

A computer code (model) was used to simulate the movement of COCs from the Site 22 Landfill. Computer simulations were conducted for all COCs (20) at the Site 22 Landfill. The COC concentrations predicted at a downgradient POE, were calculated as a percentage reduction from the initial COC concentration, due to hydrodynamic dispersion, sorption, and biodegradation. These percentage reductions in the modeled concentrations at the POE were then used to develop the AF.

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2.0 OBJECTIVES

The objectives of the modeling efforts are as follows:

- Calculate analyte-specific concentration ratios to be used as attenuation factors (AFs) for the constituents of concern at the Site 22 Landfill.
- Evaluate the uncertainty associated with the modeling efforts.

The appendix is organized as follows:

- **Section 1.0** provides the introduction.
- **Section 2.0** presents the objectives and organization for the appendix.
- **Section 3.0** describes the model selection process.
- **Section 4.0** describes the model input parameters.
- **Section 5.0** presents the model results and the AFs developed.
- **Section 6.0** provides a description of the uncertainties.
- **Section 7.0** provides a summary of results.
- **Section 8.0** includes the references used to develop this document.

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3.0 MODEL SELECTION

The principal purpose of fate and transport-modeling is to predict and quantify migration of chemicals that are subject to one or more transport mechanisms in the subsurface environment. Models are generally categorized as analytical or numerical, depending on their method of solution. Analytical models use simplifying assumptions to solve the governing equations representing mass flow and constituent transport processes. Analytical models are generally based on assumptions of uniform properties and regular geometry, and they have fairly modest data requirements (American Society for Testing and Materials, 1999). In comparison, numerical models can accommodate more complex heterogeneous systems with distributed, nonuniform properties, and irregular geometry. Numerical models typically require more data input and parameters than analytical models. In numerical modeling, cells are created to model the study area, and each cell is assigned specific aquifer properties. Numerical models are appropriate where detailed and extensive facility data are available, and the predictions sought most closely approximate three-dimensional flow and transport pathways.

Various analytical and numerical models were evaluated for possible use at the site. The models considered and the model eventually selected are discussed in this section.

3.1 MODELS CONSIDERED

The following commonly used models were considered in order to select the most appropriate model for site conditions, data availability, and desired results.

- MODFLOW
- Visual MODFLOW
- AT123D
- BIOCHLOR
- FLOWPATH II
- SESOIL
- VS2DT
- MOFAT
- MIGRATE
- AquaChem
- MINTEQA2
- HELP
- MODFLOW-SURFACT
- AQUA3D
- BIOPLUME
- BIOSCREEN
- RITZ
- VIP
- 3DEMFACT
- SOLUTRANS
- POLLUTE
- BALANCE
- PHREEQE
- VS2DT

- PESTAN
- SLAEM/MLAEM
- VISUAL PEST
- WINTRAN
- RBCA Tier 2 Analyzer
- VAM2D
- FEFLOW
- BIOF&T 2-D/3-DMOCDENSE
- FLONET/TRANS
- HYDROGEOCHEM
- BIOPLUME
- MOC
- MULTIMED
- PRZM3
- SUTRA
- WINFLOW
- CHEMFLO
- MicroFEM
- MT3D or MS-VMS
- BIOSCREEN

Professional experience with many of the models was a determining factor in model selection. Additionally, model documentation was reviewed to evaluate applicability to the problem and the types of data inputs required.

Based on further evaluation of various model capabilities, including type of model, date of latest update, solution method, capabilities, benefits, limitations, regulatory acceptance, and required input parameters, the three models listed below were considered for a more detailed evaluation:

- AT123D
- FLONET/TRANS
- MT3D or MS-VMS (both based on MODFLOW)

All three codes listed above incorporate advective-dispersive flow, adsorption, and biodegradation. The Analytical Transient 1-, 2-, 3-Dimensional (AT123D) code (Yeh, 1981) is an analytical code able to handle one-, two-, or three-dimensional problems. FLONET/TRANS is a two-dimensional finite element numerical code, and MT3D is a three-dimensional numerical fate and transport code.

3.2 FINAL MODEL SELECTION

Uncertainty enters into any modeling effort because of the randomness of natural systems, sample measurement error, the limited number of observations used to characterize a natural system, and simplifying assumptions inherent in models. A numerical model requires detailed knowledge of the site. Although many data have been collected at the Site 22 Landfill over the years, uncertainty still exists in the subsurface environment. Therefore, a simpler, and more conservative, analytical approach was chosen to estimate groundwater flow and transport in the study area.

The Department of the Navy (Navy) selected the AT123D model as the analytical model for use at Site 22. The AT123D model is a U.S. Environmental Protection Agency (EPA)-accepted analytical groundwater transport model. The EPA Personal Computer Version of the Graphical Exposure Modeling System Website (<http://www.epa.gov.opptintr/cahp/actlocal/pegems.html>) (EPA, 2005) supports using AT123D for modeling and provides further information at its Website and documents previous AT123D model usage. One example is the Weld County Waste Disposal Site in Weld County, Colorado. This project involved closure of an exploration and production waste disposal facility where AT123D was used to establish acceptable groundwater concentrations for EPA's approval (<http://www.mines.edu/research/PTTC/cases/weld/weld.html>) (Colorado School of Mines, 2005). Another example is the nearby Site 1 Landfill, also located at the former Naval Air Station Moffett Field. This municipal solid waste landfill is also undergoing post-closure monitoring. The *Final Technical Memorandum Site 1 Groundwater Evaluation Process* (Tetra Tech FW, Inc. [TtFW], 2004a) documents the detection monitoring program and the use of the AT123D model to develop attenuation factors that are applied to screening values to calculate site-specific and chemical-specific concentration limits. The document was approved by the EPA and the San Francisco Bay Regional Water Quality Control Board. AT123D was also recommended in the February 2001 Restoration Advisory Board meeting minutes for the Long Beach Naval Complex.

AT123D was originally developed by Yeh (1981) to simulate leaching from landfills. The fate and transport processes accounted for are advection, dispersion, adsorption, and decay of contaminants. The model assumes that the aquifer is homogenous and isotropic with near horizontal groundwater flow, computes the spatial-temporal concentration distribution of the constituents of concern (COCs) in an aquifer, and predicts the transient spread of a COC plume. This assumption is appropriate for the Site 22 Landfill based on the lithologic descriptions, boring logs, and borehole geophysical logs provided in the *Final Remedial Action Report for Installation Restoration Site 22 Landfill* (TtFW, 2004b).

3.3 MODEL VERIFICATION

The analytical results from each AT123D (Yeh, 1981) model run were compared to results from BIOCHLOR (EPA, 2000). BIOCHLOR uses an analytical solution for chemical transport. The BIOCHLOR model is in the public domain and is programmed from an Excel spreadsheet environment. Like AT123D, the EPA Biochlor model (based on the Domenico analytical solute transport model [Domencio and Schwartz, 1987]) uses three-dimensional dispersion, groundwater flow velocity, and biodegradation to predict the spatial and temporal decrease in chemical concentrations with increasing distance from the source. Both solutions (AT123D and BIOCHLOR) gave comparable results when using the same input parameters under similar modeling scenarios.

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4.0 MODEL INPUT PARAMETERS

The model input parameters required by Analytical Transient 1-, 2-, 3-Dimensional fall into two categories: parameters dependent on the chemical being analyzed and parameters dependent on site conditions.

4.1 CHEMICAL-DEPENDENT PARAMETERS

Chemical-dependent parameters are as follows:

- Soil-water partitioning coefficient (K_{oc}) value (organic carbon basis)
- Half-life (t_{half}) (organics)

Chemical-dependent parameter values for K_{oc} and half-lives were tabulated from multiple sources. A source preference hierarchy was developed (with U.S. Environmental Protection Agency [EPA] published values given the highest priority), and the values were distributed in Table D.4-1 based on this hierarchy (with values placed in columns to the left taking precedence over values placed in columns to the right). The source preference hierarchy for these parameters is defined on Table D.4-1. For example, to select an appropriate K_{oc} value for trichloroethene (TCE), the first column was examined. If a value from EPA was available in this column, it was selected. If a value was not available from this column (EPA source), a value from the next column to the right was selected. If a value was not available in the second column, the third column was used, and so forth, until a value was found. A similar methodology was used to select the appropriate half-life for the model.

If a range of values was encountered in the applicable column, the value yielding the most conservative (highest concentration) result was selected. Consequently, the lowest value in a range of values for K_{oc} was chosen, while the longest half-life in the range was selected.

4.2 SITE-DEPENDENT PARAMETERS

The following site-dependent parameters were fixed in all model runs:

- Travel distance (250 feet from monitoring well WGC2-8 to the Northern Channel at a 45-degree angle to the predominant westerly groundwater flow direction)
- Hydraulic conductivity = 1.0×10^{-2} centimeters per second (cm/sec)
- Hydraulic gradient = 0.0014 foot per foot (ft/ft)
- Longitudinal dispersion = $0.1 \times$ travel distance = 25 feet
- Transverse dispersion = $0.01 \times$ travel distance = 2.5 feet

- Vertical dispersion = $0.001 \times$ travel distance = 0.25feet
- Soil bulk density = 1.51 grams per cubic centimeter (cm/sec)
- Simulation time = 105 years (This represents 55 years since the cessation of waste disposal, plus 50 years of future monitoring.)
- Source thickness = 10 feet (based on the actual dimensions of the landfill)
- Source width = 500 feet (based on the actual dimensions of the landfill)
- Source of chemicals = continuous (infinite)
- Fraction organic carbon (f_{oc}) = 0.004

Conservative parameters were used for the entire evaluation. The Northern Channel was considered as the closest point of exposure (POE) in order to be conservative, although a majority of the groundwater is interpreted to be captured by pumping at Building 191, which has a regional impact on the groundwater flow regime. It is possible that a small component of groundwater from the Site 22 Landfill may discharge directly to the nearby Northern Channel. A conservative distance of 250 feet was used, representing the distance from monitoring well WGC2-8 to the POE, at a 45-degree angle to the predominant groundwater flow direction (Figure D.4-1).

The hydraulic conductivity of the shallow aquifer beneath the Site 22 Landfill between monitoring well WGC2-8 and the nearest POE has not been determined in the field by aquifer testing. The hydraulic conductivity value used in the model (10^{-2} cm/sec) is representative of sandy material (Freeze and Cherry, 1979). However, the site-specific conditions show that the aquifer is dominated by fine-grained clays and silts (see Section 2.3 of the Post-Closure Operations, Maintenance, and Monitoring Plan Addendum) with typical hydraulic conductivities ranging from 10^{-6} to 10^{-8} range (Freeze and Cherry, 1979). There is, however, a possibility of sandy lenses that have not been observed. To be conservative, therefore, a hydraulic conductivity four plus orders-of-magnitude larger than the largest observed value was used (10^{-2} cm/sec).

The hydraulic gradient at the site is relatively consistent throughout the year at 0.0014 ft/ft, as the groundwater flows toward the west.

TABLE D.4-1

**K_{oc} AND HALF-LIVES FOR ORGANIC CONSTITUENTS, SITE 22,
FORMER NAS MOFFETT FIELD**

	K _{oc} ¹ (mL/g)	K _{oc} ² (mL/g)	K _{oc} ³ (mL/g)	K _{oc} ⁴ (mL/g)	K _{oc} ^{5a-e} (mL/g)	K _{oc} ⁶ (mL/g)	Half-life ⁷ (hours) <i>Groundwater</i>	Half-life ^{5a-e} (hours) <i>Groundwater</i>	Half-life ⁷ (hours) <i>Anaerobic</i>
VOCs									
Benzene	58.9	59	62	58.9	12 - 102	83	240 - 17,280	240 - 17,280	2,688 - 17,280
Chlorobenzene	219	220	224	219	83 - 832	330	3,264 - 7,200	3,264 - 7,200	6,528 - 14,400
Chloroform	39.8	40	53	39.8	28 - 617	31	1,344 - 43,200	1,344 - 43,200	168 - 672
cis-1,2-Dichloroethene	35.5	36	35.5	35.5	49	59 ^(f)	1,344 - 69,000 ^(g)	1,344 - 69,000	2,688 - 17,280 ^(g)
Ethylbenzene	363	360	204	363	95 - 1,096	1,100	144 - 5,472	144 - 5,472	4,224 - 5,472
m-Xylene	407	--	196	407	110 - 1,413	300	336 - 8,640	336 - 8,640	672 - 12,688
p-Xylene	389	--	311	389	112 - 1,202	240	336 - 8,640	336 - 8,640	672 - 2,688
o-Xylene	363	--	241	363	48 - 537	260	336 - 8,640	336 - 8,640	4,320 - 8,640
Toluene	182	--	140	182	13 - 708	300	168 - 672	168 - 672	1,344 - 5,040
Trichloroethylene	166	160	94	166	2 - 2,692	130	7,704 - 39,672	7,704 - 39,672	2,352 - 39,672
Vinyl chloride	18.6	19	18.6	18.6	8 - 57	57	1,344 - 69,000	1,344 - 69,000	2,688 - 17,280
Pesticides									
Aldrin	2,450,000	--	48,690	2,450,000	407 - 1,513,561	96,000	24 - 28,400	24 - 28,400	24 - 168
gamma-BHC (Lindane)	1,070	--	1,352	--	1 - 43,651	--	142 - 5,765	>7,200	142 - 734
SVOCs									
1,4-Dichlorobenzene	--	620	--	617	269 - 398,107	1,700	1,344 - 8,640 ^(1,2)	--	2,880 - 17,280 ^(1,2)
2-Methylnaphthalene	--	--	--	--	2,512 - 8,511	4,500	239 - 10,000 ^(h)	--	--
4-Methylphenol	--	--	--	--	--	17	68 - 12,624 ⁽ⁱ⁾	--	--
bis(2-Ethylhexyl)phthalate	15,100,000	--	111,100	15,100,000	--	--	240 - 9,336	--	980 - 9,336
Carbazole	3,390	--	3,390	3,390	--	--	29,280 ^(j)	--	(29,280 - 26) ^(j)
Dibenzofuran	--	7,800	--	8,128.30	--	--	205 - 835	--	672 - 2,688
Diethylphthalate	288	--	82	288	--	69	144 - 2,688	--	672 - 5,376
Fluorene	13,800	--	7,707	13,800	5,754 - 295,121	7,300	1,536 - 2,880	1,536 - 2,880	3,072 - 5,760
Naphthalene	2,000	--	1,191	2,000	239 - 100,000	940	24 - 6,192	5,256	600 - 6,192

TABLE D.4-1

**K_{oc} AND HALF-LIVES FOR ORGANIC CONSTITUENTS, SITE 22,
FORMER NAS MOFFETT FIELD**

Notes:

- No available data.
- (a) Calculated from solubility provided in McKay using equation 4-7 given in Lyman et al., 1987
- (b) Calculated from smallest K_{ow} provided in McKay et al. and following relationship given in McKay: K_{oc} = 0.41 K_{ow}.
- (c) Values estimated from 1,3-dichloropropene
- (d) Values estimated from 1,2,4-trichlorobenzene
- (e) Values estimated from 1,2-dichloropropane
- (f) Values estimated from trans-1,2-dichloroethene
- (g) Values estimated from 1,2-dichloroethene
- (h) Values based on naphthalene
- (i) Values based on 2,4-dinitrophenol
- (j) Values based on dibenzofuran

References 2 and 5. The rate of biodegradation in groundwater was assumed to be one-half that in surface waters. Overall, half-lives were conservatively estimated to be twice the unacclimated aqueous aerobic biodegradation half-lives unless the data suggested otherwise. For chemicals that degraded rapidly under anaerobic conditions, the low half-life in groundwater usually equaled the low aqueous anaerobic biodegradation half-life, and the high half-life was based upon the high aqueous aerobic biodegradation half-life.

Reference 6. Biodegradation has been less studied than under aerobic conditions, and for many chemicals, information was not available. Unless experimental data were located, aerobic biodegradation half-lives were conservatively estimated to be four times longer than the range for aerobic biodegradation.

Abbreviations and Acronyms:

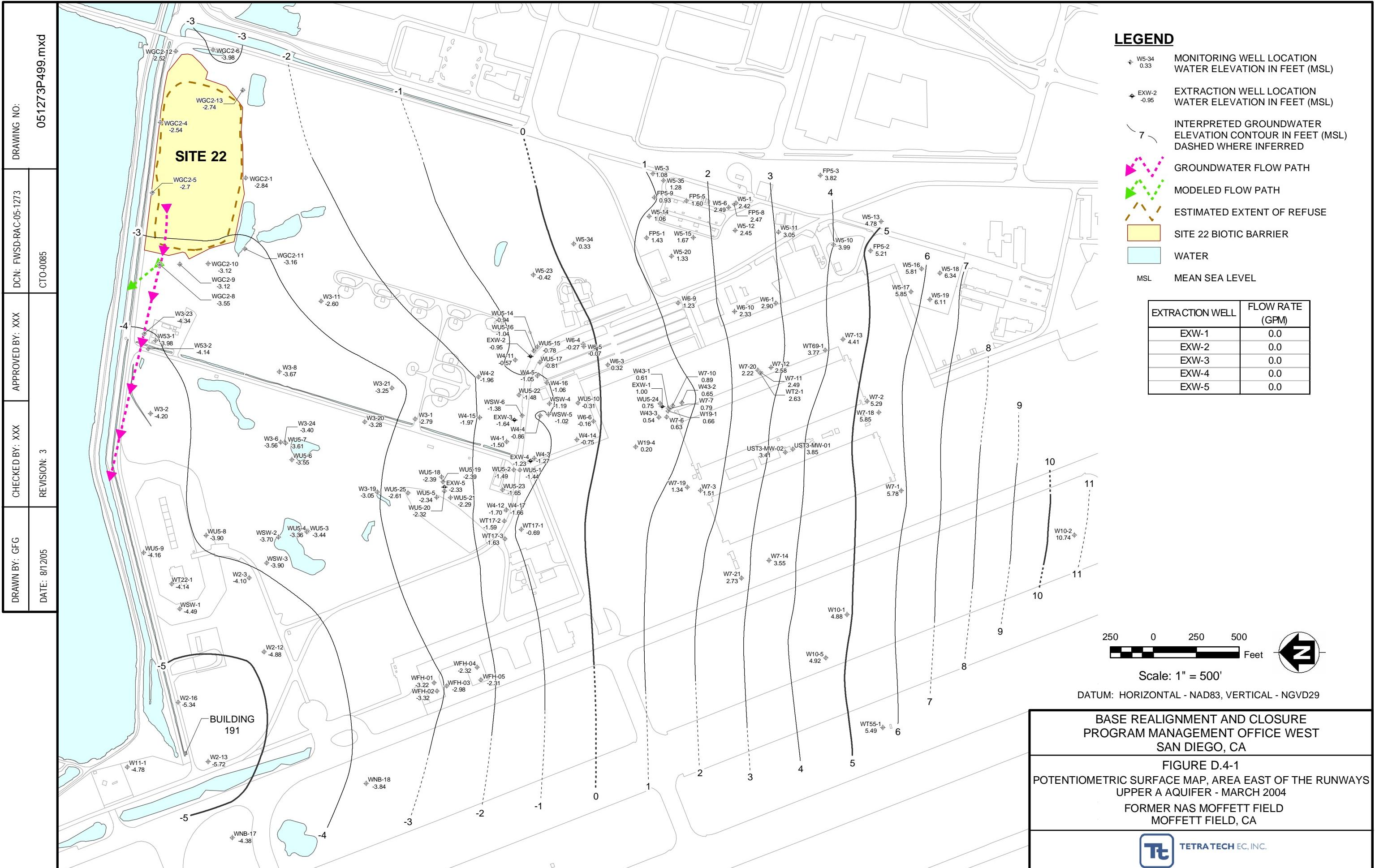
- BHC – benzene hexachloride
- K_{oc} - soil-water partitioning coefficient
- ml/g – milliliters per gram
- NAS - Naval Air Station
- SVOC – semivolatile organic compound
- VOC – volatile organic compound

References:

References are listed in the order of priority, e.g., if the first listed reference does not have a value, the second listed reference is checked for a value and so forth.

K_{oc} Values

- (1) U.S. Environmental Protection Agency, 1996
- (2) California Environmental Protection Agency, 2002
- (3) Washington State Department of Ecology, 2001
- (4) Department of Energy, 2002
- (5a) McKay, D., W. Y. Shiu, and K. C. Ma, 1992a
- (5b) McKay, D., W. Y. Shiu, and K. C. Ma, 1992b
- (5c) McKay, D., W. Y. Shiu, and K. C. Ma, 1993
- (5d) McKay, D., W. Y. Shiu, and K. C. Ma, 1995a
- (5e) McKay, D., W. Y. Shiu, and K. C. Ma, 1995b
- (6) Strenge, D.L. and S.R. Peterson, 1989. Values selected from pH range of 5 to 9 and clay content of 10 to 30 percent and >30 percent, respectively.
- (7) Howard, P. H., R. S. Boethling, W. F. Jarvis, W. M. Meylan, E. M. Michalenko. 1991



5.0 CALCULATION OF ATTENUATION FACTORS - RESULTS

The model was run to obtain an analyte-specific concentration ratio that was used, as applicable, as an analyte-specific attenuation factor (AF) for each constituent of concern (COC). The concentration ratios, or AFs, are calculated as $C_0/C_{\text{downgradient}}$, where C_0 is the concentration at monitoring well WGC2-8, and $C_{\text{downgradient}}$ is the predicted downgradient concentration at the evaporation pond. Chemical attenuation occurs due to advection-dispersion, adsorption, and biodegradation.

The concentration ratios modeled for the COCs at Site 22 are listed in Table D.5-1. If the COC was predicted to fall short of the point of exposure, the model gave a result of zero concentration, which is an infinite AF. Table D.5-2 presents the AFs and the concentration limits for each COC. The COCs list includes total xylene (see Table 1-1 of the Post-Closure Operations, Maintenance, and Monitoring Plan Addendum), whereas the tables in this appendix include values for each xylene isomer¹.

¹ The analytical method does not differentiate between the m-xylene isomer and the p-xylene isomer, but groups them together. For the purposes of modeling, the m-xylene isomer and p-xylene isomer were evaluated individually to determine which analyte represented the more conservative approach. Consequently, the list of volatile organic compounds shown on the tables in this appendix include values for both m-xylene and p-xylene.

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TABLE D.5-1
**CONCENTRATION RATIOS CALCULATED FOR CONSTITUENTS OF CONCERN, SITE 22,
FORMER NAS MOFFETT FIELD**

COCs	K _{oc} (mL/g)	f _{oc}	Adsorption Coefficient (m ³ /kg)	Half-life (hours)	Half-life (years)	Lambda ^(a) (1/hrs)	Concentration ratio
VOCs							
Benzene	58.9	4.0E-03	2.36E-04	17,280	1.97	4.01E-05	2.57E+01
Chlorobenzene	219	4.0E-03	8.76E-04	7,200	0.82	9.63E-05	7.80E+04
Chloroform	39.8	4.0E-03	1.59E-04	43,200	4.93	1.60E-05	4.87E+00
cis-1,2-Dichloroethene ^(b)	35.5	4.0E-03	1.42E-04	69,000	7.87	1.00E-05	3.03E+00
Ethylbenzene	363	4.0E-03	1.45E-03	5,472	0.62	1.27E-04	3.95E+07
Toluene	182	4.0E-03	7.28E-04	672	0.08	1.03E-03	2.56E+17
Trichloroethylene	166	4.0E-03	6.64E-04	39,672	4.53	1.75E-05	2.45E+01
Vinyl Chloride	18.6	4.0E-03	7.44E-05	69,000	7.87	1.00E-05	2.58E+00
Xylene (total) ^(c)	386.00	4.0E-03	1.54E-03	8,640	0.99	8.02E-05	9.93E+05
Pesticides							
Aldrin	2.45E+06	4.0E-03	9.80E+00	28,400	3.24	2.44E-05	infinite
gamma-BHC (Lindane)	1,070	4.0E-03	4.28E-03	7,200	0.82	9.63E-05	infinite
SVOCs							
1,4-Dichlorobenzene	617	4.0E-03	2.47E-03	8,640	0.99	8.02E-05	6.42E+07
2-Methylnaphthalene	2,512	4.0E-03	1.00E-02	336	0.04	2.06E-03	infinite
4-Methylphenol ^(d)	12,300	4.0E-03	4.92E-02	14,624	1.67	7.91E-04	3.50E+10
bis(2-Ethylhexyl)phthalate	1.51E+07	4.0E-03	6.04E+01	9,336	1.07	7.42E-05	infinite
Carbazole	3,390	4.0E-03	1.36E-02	29,280	3.34	2.37E-05	infinite
Dibenzofuran	7,800	4.0E-03	3.12E-02	835	0.10	8.30E-04	infinite
Diethylphthalate	288	4.0E-03	1.15E-03	2,688	0.31	2.58E-04	1.24E+10
Fluorene	13,800	4.0E-03	5.52E-02	2,880	0.33	2.41E-04	infinite
Naphthalene	2,000	4.0E-03	8.00E-03	6,192	0.71	1.12E-04	1.88E+19

Notes:

- (a) Lambda is a parameter used by the model
- (b) 1,2-Dichloroethene is used as a surrogate
- (c) m-Xylene is used as a surrogate
- (d) 2-Methylphenol is used as a surrogate

Abbreviations and Acronyms:

- BHC - benzene hexachloride
 COC – constituent of concern
 f_{oc} – fraction organic carbon
 hrs - hours
 K_{oc} – soil-water partitioning coefficient
 m³/kg - cubic meter per kilogram
 mL/g – milliliters per gram
 NAS – Naval Air Station
 SVOC – semivolatile organic compound
 VOC – volatile organic compound

TABLE D.5-2
**CONCENTRATION LIMITS FOR CONSTITUENTS OF CONCERN, SITE 22
FORMER NAS MOFFETT FIELD**

CO _C ^(a)	Saltwater Value ^(b) (µg/L)	Concentration Ratio	Attenuation Factor	Calculated Concentration Limit ^(c) (µg/L)
VOCs				
Benzene	700	2.57E+01	25.70	17,990.00
Chlorobenzene	129	7.80E+04	100	12,900.00
Chloroform	2.8	4.87E+00	4.87	13.64
cis-1,2-Dichloroethene ^(d)	59	3.03E+00	3.03	178.77
Ethylbenzene	43	3.95E+07	100	4,300.00
Toluene	5,000	2.56E+17	100	500,000.00
Trichloroethylene	4.7	2.45E+01	24.50	115.15
Vinyl chloride ^(d)	59	2.58E+00	2.58	152.22
Xylene (total) ^(e)	0.18	9.93E+05	100	18.00
Pesticides				
Aldrin	0.13	infinite	100	13.00
gamma-BHC (Lindane)	0.016	infinite	100	1.60
SVOCs				
1,4-Dichlorobenzene	129	6.42E+07	100	12,900.00
2-Methylnaphthalene	30	infinite	100	3,000.00
4-Methylphenol ^(f)	1.3	3.50E+10	100	130.00
bis(2-Ethylhexyl)phthalate	0.3	infinite	100	30.00
Carbazole ^(g)	0.37	infinite	100	37.00
Dibenzofuran	0.37	infinite	100	37.00
Diethylphthalate	3.4	1.24E+10	100	340.00
Fluorene	30	infinite	100	3,000.00
Naphthalene	235	1.88E+19	100	23,500.00

Notes:

- (a) Analytes that did not appear in any of the four criteria sources were assigned surrogates. Surrogates were chosen based on the criteria described in Section 4.1.1 of the OMMP Addendum.
- (b) Saltwater chronic value was derived by applying a safety factor of 10 if the most appropriate criteria available were saltwater acute or freshwater chronic values.
- (c) Calculated concentration limit was the chronic saltwater value multiplied by the attenuation factor.
- (d) 1,2-Dichloroethene was used as a surrogate
- (e) m-Xylene was used as a surrogate
- (f) 2-Methylphenol was used as a surrogate. 3/4-Methylphenol reported by analytical laboratory.
- (g) Dibenzofuran was used as a surrogate

* The sample quantitation limit is based on the specific analytical methods listed in the OMMP (TtFW, 2003).

Abbreviations and Acronyms:

- µg/L – micrograms per liter
 BHC - benzene hexachloride
 COC – constituent of concern
 NAS – Naval Air Station
 OMMP – Operations, Maintenance, and Monitoring Plan
 SVOC – semivolatile organic compound
 TtFW - Tetra Tech FW, Inc.
 VOC – volatile organic compound

6.0 UNCERTAINTIES

Many uncertainties are associated with attempts to predict chemical concentrations when moving away from a source. Some of the uncertainty results from the simplifying assumptions inherent in the models used. Additional uncertainties result from the random nature of real systems, sample measurement error, and the limited number of observations used to characterize a natural system. The Department of the Navy (Navy) accounted for uncertainty/variability in the modeling, the natural hydrogeological system, and chemical-specific geochemical fate and transport process by applying a layered conservative approach:

- Conservative input parameters resulting in conservative (largest) estimates of concentrations
- Truncating the calculated attenuation factors to 100

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7.0 SUMMARY OF RESULTS

Attenuation factors (AFs) were developed based on the concentration ratios calculated using Analytical Transient 1-, 2-, 3-Dimensional (AT123D), and they were checked using BIOCHLOR for all analytes. The concentration ratios, or AFs, are reported in Table D.5-1. Of the original 20 constituents of concern (COCs), the following types and numbers of chemicals had concentration ratios lower than 100, meaning that the concentration 250 feet downgradient of the monitoring well would be greater than 1/100th of the concentration in the monitoring well. The concentration ratios are summarized below:

- Five of 9 volatile organic compounds had concentration ratios lower than 100.
- Zero of 2 pesticides had concentration ratios lower than 100.
- Zero of 9 semivolatile organic compounds had concentration ratios lower than 100.

The concentrations predicted from the modeling are conservative. Because the AFs were calculated based on the predicted concentrations, the AFs are also conservative. This conclusion is consistent with the methodology used in the AT123D modeling, where conservative values were used as input parameters.

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APPENDIX E

STATISTICAL ANALYSIS

**Base Realignment and Closure
Program Management Office West
1230 Columbia Street, Suite 1100
San Diego, California 92101**

**CONTRACT NO. N68711-98-D-5713
CTO No. 0085**

APPENDIX E

DRAFT

STATISTICAL ANALYSIS

Revision 0

August 12, 2005

**FORMER NAVAL AIR STATION MOFFETT FIELD
MOFFETT FIELD, CALIFORNIA**

DCN: FWSD-RAC-05-1273



TETRA TECH EC, INC.

**1230 Columbia Street, Suite 500
San Diego, CA 92101**

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ABBREVIATIONS AND ACRONYMS

ASTM	American Society for Testing and Materials
CCL	calculated concentration limit
CCR	California Code of Regulations
CRQL	contract-required quantitation limit
DTSC	Department of Toxic Substances Control
EPA	U.S. Environmental Protection Agency
MDL	method detection limit
ND	non-detect
SQL	sample quantitation limit
VOC	volatile organic compound

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1.0 INTRODUCTION

The California Code of Regulations (CCR), Title 27, § 20415, identifies statistical methods to be considered when evaluating analytical data. This appendix presents a process by which groundwater data are evaluated to determine whether constituent concentrations in downgradient wells have been influenced by the Site 22 Landfill at Former Naval Air Station Moffett Field (Moffett).

This introductory section includes discussion of the guidance documents consulted to develop the approach to the statistical analyses described in this appendix (Section 1.1), specification of the computer software to be used for the statistical analyses (Section 1.2), and identification of the monitoring wells that will be considered as representative of background conditions for comparison to downgradient monitoring points (Section 1.3). Section 2.0 describes the data analysis process and presents flow charts that summarize the hierarchy for statistical testing. Section 3.0 delineates the statistical methodologies and the tests to be used at the Site 22 Landfill.

1.1 GUIDANCE DOCUMENTS

Title 27 CCR and U.S. Environmental Protection Agency (EPA) guidance documents (EPA, 1989; 1992; 2000) formed the basis for the overall statistical strategy described in this document. The Department of the Navy's (Navy's) *Handbook for Statistical Analysis of Environmental Background Data* (Southwest Division Naval Facilities Engineering Command, 1999) and the *Procedural Guidance for Statistically Analyzing Environmental Background Data* (Southwest Division Naval Facilities Engineering Command, 1998) were of particular importance in developing the specific statistical approach and were used as technical references for the statistical tests. The Southwest Division Naval Facilities Engineering Command documents are based, in part, on various EPA documents (including the above-cited publications) and the work of prominent environmental statisticians found in the literature. Other materials used include the American Society for Testing and Materials (ASTM) *Standard Guide for Developing Appropriate Statistical Approaches for Groundwater Detection Monitoring Programs* (ASTM, 1998) and textbooks by Gilbert (1987), Gibbons (1994), and Gibbons and Coleman (2001).

1.2 SOFTWARE PROGRAMS

The ChemStat™ software package, Version 4.0, from Starpoint Software was used to analyze the data. This software package can perform most of the required statistical analyses. It was originally developed for the statistical analysis of groundwater monitoring data at Resource Conservation and Recovery Act, Subtitle C and D, facilities (following the guidelines set forth in EPA, 1989; 1992). For those specific tests where ChemStat™ does not have a statistical routine,

an Excel spreadsheet has been used to program any iterative calculations based on the statistical formulas in the *Handbook for Statistical Analysis of Environmental Background Data* (Southwest Division Naval Facilities Engineering Command, 1999).

1.3 BACKGROUND CONCENTRATIONS

To identify wells that potentially exhibit results that are measurably significant at the Site 22 Landfill, concentrations of chemicals in downgradient groundwater can be compared to concentrations that are likely to occur in the absence of site-related activities (represented by background [upgradient or reference] wells). Background is defined in Title 27 CCR, § 20164 as the concentrations, measures of constituents, or indicator parameters in water or soil not affected by waste constituents or by leachate from the monitored waste management unit. Background concentrations are due to naturally occurring substances and other anthropogenic sources unrelated to site activities. Background concentrations can also be used to assist in the selection of remedial goals or cleanup levels and to identify volumes of impacted groundwater.

Groundwater elevation data collected from the monitoring well network at the Site 22 Landfill were reviewed, and the potentiometric surface was contoured to identify groundwater flow directions. These data were contoured using the most recent well leveling survey to provide a consistent reference datum for the entire network (see Appendix A). Groundwater flow directions were consistently toward the west. Based on this general flow direction, background wells identified for the Site 22 Landfill include wells WGC2-4 and WGC2-13. These wells are hydraulically upgradient of the Site 22 Landfill mass. The spatial location of these wells should account for most of the groundwater underflow that would enter beneath the Site 22 Landfill, as well as water that might infiltrate from the nearby evaporation ponds to combine with the groundwater underflow. Wells WGC2-6 and WGC-12 are reference wells that are located east of the upgradient wells. Due to a hydrologic divide that is interpreted to lie between these wells and the upgradient wells, the reference wells are not considered true background wells, as these wells may not yield information regarding groundwater that passes beneath Site 22. However, because of their proximity to the site, these wells will be pooled together with the upgradient wells as the background data set.

2.0 ANALYSIS PROCESS

2.1 DATA COLLATION AND INITIAL REVIEW

Before conducting statistical analyses, the data will be filtered to eliminate chemicals for which all analyses were reported as non-detects (ND). The analytical laboratory reports a sample as ND when it cannot distinguish the signal characteristic of the sample from background noise (the method detection limit [MDL¹]). When all the data for a chemical are NDs, no statistical analyses will be performed, because there is no difference between the two groups of data (background and downgradient monitoring wells). Additionally, any NDs with MDLs above the calculated concentration limits (CCLs) used for comparison, or any NDs without a corresponding MDL, will be eliminated from statistical analysis. In both cases, analytical results cannot be differentiated from background noise at a critical threshold level for an appropriate comparison.

2.2 HANDLING OF FLAGGED VALUES

Laboratory analytical results that fall below particular quantification thresholds are generally flagged with data qualifiers during the data validation process. The two most common flags signal one of two results: either the sample was below an analytical detection threshold (which is usually termed “ND”), or it was above the detection threshold, but was below a particular quantification threshold (usually termed “estimated”). Each of these situations is discussed below.

2.2.1 Non-detects

Analytical results are never reported as zero; they are reported as ND, referenced to being lower than some analytical threshold, and generally flagged with a “U” qualifier. U.S. Environmental Protection Agency (EPA) (1992 and 2000), Naval Facilities Engineering Command Southwest (Southwest Division Naval Facilities Engineering Command; 1998) and Department of Toxic Substances Control (DTSC; 2001) guidance documents suggest caution in choosing censoring limits and estimated concentrations values for parametric statistical analyses. Possible choices include the MDL, the sample quantitation limit (SQL)², and the contract-required quantitation

¹ The MDL is the lowest quantity of a chemical that can be detected. It is based on the signal-to-noise ratio. It assumes ideal laboratory conditions.

² The SQL represents the chemical concentration that can be reliably and reproducibly detected. It takes matrix interferences into account. It is what is achievable in the field.

limit (CRQL)³. All of the guidance documents concur that the SQL or MDL is preferred over the CRQLs, because the CRQLs are not necessarily the lowest detectable values possible.

EPA (1992; Section 2) states that the SQL should be taken as the reasonable upper bound on chemical concentrations and that the MDL should never be used to place an upper bound on chemical concentrations characterized by an ND value. However, more recent EPA guidance (EPA, 2000; Section 4.7.1) provides for replacement of NDs with a surrogate, usually half of the MDL, if the percentage of NDs is lower than 15 percent. For larger percentages (greater than 15 percent, but lower than 50 percent), EPA (2000) recommends a censoring technique such as winsorizing, trimming, or replacement methods (Aitchison or Cohen methods) if parametric statistics are being performed (EPA, 2000, Section 4.7.2). Southwest Division Naval Facilities Engineering Command guidance (Southwest Division Naval Facilities Engineering Command; 1998, Section 3.1.5) concurs with the EPA 2000 suggestions. DTSC (2001; Section 2.3) also concurs that the MDL, not the SQL, should be the censoring point.

Replacement of NDs only becomes an issue in parametric statistical analyses. Nonparametric analyses usually rely on rank ordering techniques for statistical hierarchy; so NDs do not have to be replaced because they will generally rank below detected values. For purposes of parametric statistics, NDs will be replaced with half of the MDL when the number of NDs is lower than 15 percent of the data set (see Section 3.1 for detailed statistical methodology).

2.2.2 Estimated Values

Analytical data that are quantitated above the MDL, but that are below the SQL, are considered estimated values and are generally flagged with a “J” qualifier for organic analyses and a “J” or a “B” qualifier for inorganic analyses. Uncensored measurements are usually better estimates than any proxy concentrations and allow for better characterization of site conditions (Naval Facilities Engineering Service Center, 2000). Both federal (EPA, 1992; Section 2) and state agencies (DTSC, 2001; Section 2.3.1) advocate the use of the actual measurements, rather than relying on replacements or proxy values. Consistent with EPA (1992) and DTSC (2001) guidances, estimated values will be used as reported. [Both the EPA (2000) and Southwest Division Naval Facilities Engineering Command (1998) guidance documents are silent on this subject.]

The use of estimated values is not expected to be a concern for the data set at the Site 22 Landfill. As described in Section 2.2.1, replacement values only become potential concerns for parametric statistics, and replacement with half of the MDL would only occur if non-detected values were lower than 15 percent of the data set. The rank ordering algorithms in nonparametric

³ The CRQL is the detection limit that EPA requires in the Contract Laboratory Program. It is not necessarily the lowest achievable value.

statistics will assign lower ranks to estimated values than those assigned to unqualified data (data quantified above the SQL). Estimated data concentrations used “as is” may be lower than some non-detected concentrations that are assigned values of half of the MDL if the MDL in the latter case is greater than the SQL in the former circumstance. However, most parametric analyses assign larger ranks to estimated samples than those assigned to non-detected samples.

2.3 HYPOTHESIS TESTING

One way to test a hypothesis is to review the means of two populations and determine if they are significantly different from, for example, a t-test. Testing the significance of the difference between means of two independent small samples requires that both distributions be normal and that the population standard deviations be equal. These assumptions do not hold for most of the constituent populations evaluated at Site 22. Further, with regard to an individual concentration, it is inappropriate to compare a population mean to an individual concentration; therefore, alternative or nonparametric methods are used to reject or accept the hypothesis that two populations that do not exhibit normality are equivalent to a specified level of confidence. Nonparametric methods use the ranks of the observations rather than the original observations. Therefore, a true mean of the population is not calculated, though the null hypothesis is still evaluated.

The null hypothesis⁴ to be tested is that the downgradient well, groups of wells, or individual samples come from the same population as the background data. Significance levels will be set at $\alpha = 0.05$. A significance level of 0.05 means there is a less than 5 percent chance of committing a Type I error, that is, concluding that site data differ from background data when, in fact, they are the same (EPA, 2002). If chemical concentrations for the selected background population are significantly lower than concentration data from the population thought to represent a downgradient well, it is assumed that the two selected populations (downgradient well and background [upgradient and reference] well concentrations) differ from one another, and the downgradient well potentially is influenced by site conditions other than those affecting the upgradient/reference well.

2.4 PARAMETRIC AND NONPARAMETRIC STATISTICS

There are two types of statistical testing: parametric and nonparametric. Most statistical tests were originally developed based on the assumption that data are distributed along a normal distribution. These tests are called parametric because the information contained in the data can be summarized by specific parameters, usually the mean and standard deviation (Helsel and

⁴ The null hypothesis describes what is assumed to be the true state of nature, while the alternative hypothesis describes the opposite situation.

Hirsch, 1992). In tests of this nature, a test statistic is computed by using these parameters, and the hypothesis testing relies on the data following this assumed distribution. Hypothesis testing that is not based on the assumption that data follow a particular distribution is called a nonparametric test. Information contained in the data is brought to light by comparing each value to the others in the data set, instead of calculating parameters (Helsel and Hirsch, 1992). These tests are less sensitive to a greater percentage of multiple detection limits or replacement of NDs with proxy values because any of these values will have lower ranks than nonqualified values (such as concentrations above the quantitation limits). The selection of parametric versus nonparametric tests is discussed in Section 3.0, based on the percentage of NDs and differences in detection limits.

3.0 METHODOLOGY

The methodologies recommended to analyze the data from the Site 22 Landfill are illustrated by flow charts in Figures E.3-1 through E.3-3. As indicated in Figure E.3-1 and described in Section 2.1, those chemicals with all measurements below the analytical detection limits (non-detects [NDs]) will be eliminated from further analysis. Also, those values with method detection limits (MDLs) above the calculated concentration limits, or data from wells with fewer than eight measurements, will be removed from statistical analysis.

Quality of fit testing will then be performed to evaluate any underlying distribution of the data such as a normal or lognormal distribution. This step is conducted to aid in selection of either parametric or nonparametric tests, as discussed in Section 2.4. The remaining data will be divided into different groups, based on the number of NDs encountered for each chemical. The four groups are as follows:

1. Chemicals with a percentage of NDs less than 15 percent of the total analyses (Figure E.3-1)
2. Chemicals with more than 15 percent, but less than 50 percent, NDs (Figure E.3-1)
3. Chemicals with more than 50 percent, but less than 90 percent NDs (Figure E.3-2)
4. Chemicals with more than 90 percent NDs (Figure E.3-3)

3.1 NON-DETECTS LESS THAN 15 PERCENT

Figure E.3-1 shows the methodology recommended when data for a given constituent contain fewer than 15 percent NDs. As indicated in Figure E.3-1, data sets with fewer than 15 percent NDs will be tested for normality using the untransformed data and the log-transformed data (logarithm of untransformed data) and applying the Shapiro-Wilks test (if less than 50 data points) or the Shapiro-Francia test (if 50 or more data points). As indicated in Figure E.3-1, data with a normal distribution will be analyzed using parametric methods (left side of the figure including Student's or Satterthwaite's t-tests), while data that do not follow a normal distribution will be evaluated using nonparametric procedures (right side of the figure including Gehan, Wilcoxon Rank Sum, or Kruskal-Wallis tests). Homogeneity of variances will be tested using one of two methods:

- Levene's test, an analytical method recommended in U.S. Environmental Protection Agency (EPA) guidance documents (EPA, 1992).
- Box plots, used to evaluate whether the variances were equal. Equality of variance will be assumed if the box plot of each group is less than three times the length of the shortest box plot (EPA, 1992).

If the variances are equal, data will be analyzed using Student's t-test to compare the populations; otherwise, Satterthwaite's t-test will be used.

Nonparametric test selection will be based on the difference in MDLs. If there is more than one detection limit, data will be analyzed with the Gehan test. The Gehan test is a variation of the Wilcoxon Rank Sum test that addresses multiple detection limits using a modified ranking procedure, rather than treating all ties as the same rank (EPA, 2002). If all of the method detection limits are the same, the Kruskal-Wallis test will be used. EPA guidances (EPA, 1992; 2000) recommend the use of the Kruskal-Wallis and the Wilcoxon Rank Sum nonparametric methods when the data do not follow a normal distribution, or when NDs are between 15 and 90 percent. The Interim Final Guidance (EPA, 1989) recommends the Kruskal-Wallis test over the Wilcoxon Rank Sum procedure when three or more well groups (including background) are being compared.

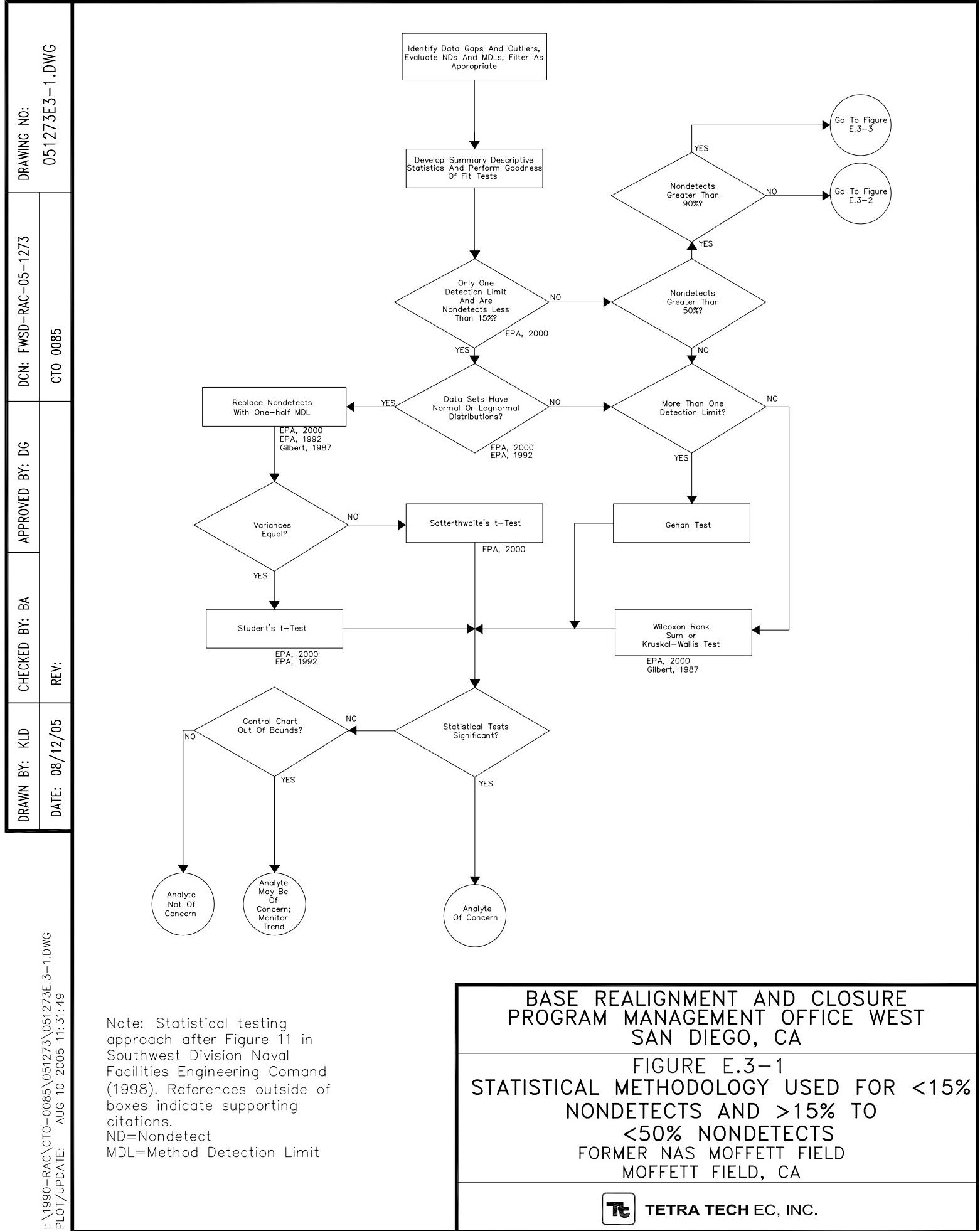
If parametric testing shows statistical significance, a regression analysis may be performed to evaluate whether there is a discernible trend to the data through time. That is, are the concentrations increasing, decreasing, or remaining constant? If nonparametric testing shows statistical significance, the Mann-Kendall Trend analysis, as discussed by Gilbert (Gilbert, 1987), may be used. The Mann-Kendall procedure would test the null hypothesis of no trend against the alternative hypotheses of an upward trend at the 95 percent confidence level. Sen's Nonparametric Estimator of Slope method can also be used to evaluate changes in concentrations over time (Gilbert, 1987). Because this is a nonparametric test, it is suitable for a large number of NDs and is relatively insensitive to outliers. For analytes where no significance was found in statistical testing, control charts will be created to monitor concentration changes through time to identify potential trends in advance of any exceedences of the CCLs.

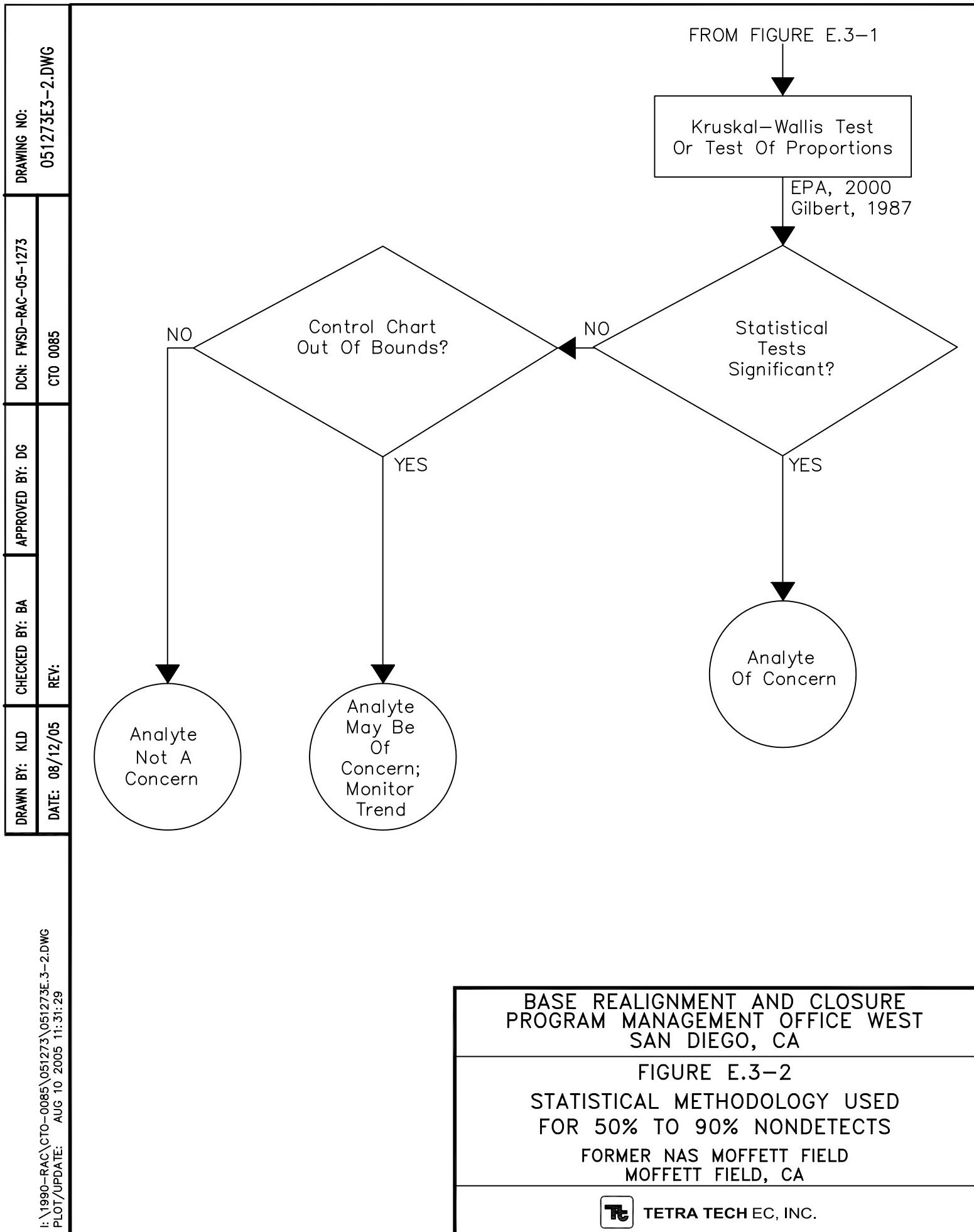
3.2 NON-DETECTS GREATER THAN 15 PERCENT AND LESS THAN 50 PERCENT

EPA (1992 and 2002) recommends nonparametric procedures when more than 15 percent NDs are encountered in a data set because of the difficulty in verifying the assumptions necessary for a parametric analysis.

1. The data are normally distributed.
2. The data residuals are normally distributed.
3. Group variances are approximately equal.

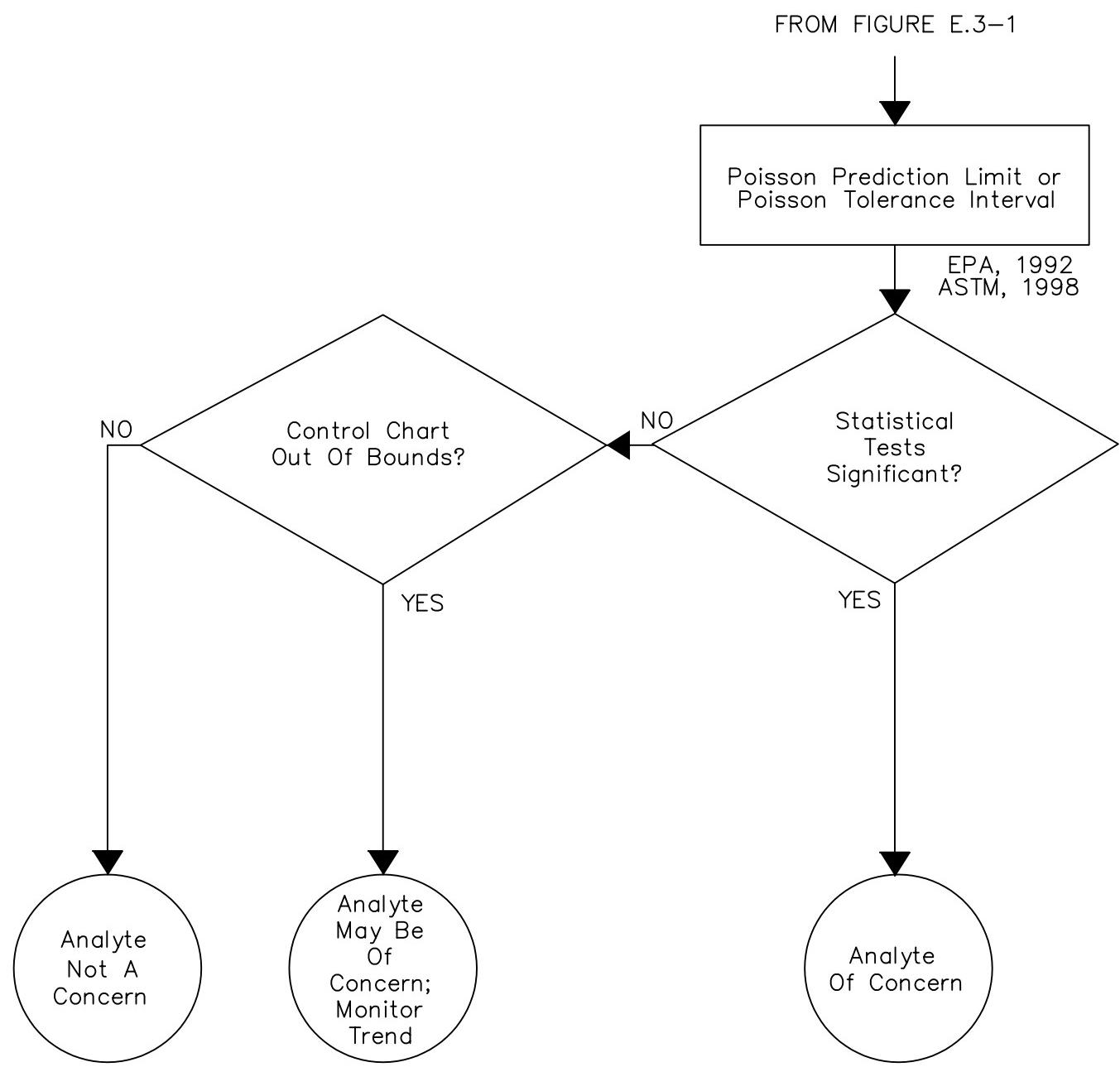
The statistical methodology to be used for analyzing constituents with between 15 and 50 percent NDs is the same as the nonparametric analyses used when there are less than 15 percent NDs, as discussed above in Section 3.1 and shown on Figure E.3-1.





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3.3 NON-DETECTS GREATER THAN 50 PERCENT AND LOWER THAN 90 PERCENT

If the percentage of NDs is greater than 50 percent, but lower than 90 percent, the Kruskal-Wallis test or the Test of Proportions will be used to test for statistical differences between downgradient and background data (see Figure E.3-2). Depending on the results of the statistical testing, the same procedures described above in Section 3.1 (control charts [see Figure E.3-1], and Mann-Kendall tests or Sen's Nonparametric Estimator of Slope) will be used to evaluate potential concentration trends over time.

3.4 NON-DETECTS GREATER THAN 90 PERCENT

EPA (1992) and American Society for Testing and Materials (1998) guidances recommend using the Poisson Prediction Limit or Poisson Tolerance Limit for greater than 90 percent NDs (see Figure E.3-3). The sum of concentrations from all background well samples for the constituent of interest will be used to determine the Poisson Prediction Limit. Concentrations over the specified sampling dates will be summed and compared to the prediction interval. The procedure will be repeated for each monitoring point. The prediction limit can also be used to set a threshold value that will trigger a response for samples not yet collected.

While the EPA 1992 guidance recommends use of the Poisson Prediction Limit, the Poisson Tolerance Limit is also included as a potential alternative based on the original application of the Poisson Prediction Limit. The prediction limit method, as originally developed by Gibbons (1987), was used to test for an entire suite of volatile organic compounds (VOCs). In Gibbons' method, "n" represented the number of VOC scans rather than the number of background samples. EPA (1992) presented the method for use with individual compounds. Gibbons (1994), the developer, argued against using the method for individual compounds and again reiterated its use for the entire suite of VOCs. Additionally, the method was developed and presented for comparison to a single monitoring well. Additional comparisons of multiple wells are not accounted for in the formula. However, EPA (1992) considers the application suitable for comparison to multiple wells on an individual basis. The ChemStat™ software program compares each downgradient monitoring well to the limit on an individual basis.

The Poisson Tolerance Limit determines an upper tolerance limit from the suite of background wells. The tolerance limit calculated from background samples will be compared to every sample in each downgradient monitoring well for each constituent to evaluate whether the tolerance limit is exceeded.

Because of the large percentage of NDs involved, the control charts will probably provide a more reliable indication of statistical significance and trend.

3.5 ALTERNATIVE METHODOLOGIES

Comparing maximum site concentrations to maximum background concentrations is not recommended by Department of the Navy guidance documents (Naval Facilities Engineering Command Southwest [Southwest Division Naval Facilities Engineering Command], 1998; 1999).

Concentrations measured in downgradient wells are often compared to concentrations in background wells to determine if elevated concentrations of constituents are present. If the downgradient and background groundwater concentration distributions for a constituent are identical, that constituent should not be identified as a concern. If the distributions are identical, however, the data set (downgradient or background) with the most measurements has a greater probability of having the highest measured concentration of a given constituent. Therefore, comparing maximum background concentrations to maximum downgradient concentrations is unacceptable because the comparison relies heavily on whether the background or downgradient wells have the most data (Southwest Division Naval Facilities Engineering Command, 1999).

4.0 REFERENCES

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